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ABSTRACT

The JASON Curriculum Project materials are designed to prepare teachers and students for an exploration around the Galapagos Islands via satellite transmission of live images and sound. This curriculum package contains five units, 25 lesson plans, and over 50 activities, along with teacher background material, student worksheets and readings, a list of resources, and a glossary. A poster, maps, and complete materials for several games and simulations are also included. The JASON Project is designed to spark student interest in science, technology, and social studies, and an interdisciplinary theme is found throughout the materials. Lesson subjects include Darwin's trip to the Galapagos, technology of underwater exploration and satellite communications, island formation, oceanography, the Galapagos ecology, mapping and expedition planning, island culture, and environmental management. (WRM)

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THE GALÁPAGOS
JASON CURRICULUM

NATIONAL SCIENCE TEACHERS ASSOCIATION

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JASON Curriculum Credits

Curriculum Director
Marily DeWall, National Science Teachers Association

Curriculum Coordinator
M. Frank Ireton, National Science Teachers Association

Social Studies Curriculum Coordinator
Sara N. L. Wallace, National Council for the Social Studies

Curriculum Editor
Mary Liston Liepold, Washington, DC

Production Editor
Peter N. Fish, Washington, DC

Editor, Social Studies
Salvatore S. Natoli, National Council for the Social Studies

Project Researcher
Jerry Wellington, University of Houston, Houston, TX

Design Director
Rob Sugar/Ted Smith, AURAS Design, Washington, DC

Illustrator
Max-Karl Winkler, Silver Spring, MD

Poster Artist
Joy Dabney, Western Washington University, Bellingham, WA

Lesson Authors and Contributors

Roger Torda, Turner Broadcasting Systems, Atlanta, GA
Ann Ashley, Falmouth High School, Falmouth, MA
Judy Bazler, Lehigh University, Bethlehem, PA
Maurice Butler, Roosevelt High School, Washington, DC
Jaré Cardinal, Rochester Museum & Science Center, Rochester, NY
Michael DiSpezio, Images, Cataumet, MA
Merle L. Douglass, Sippican School, Marion, MA
Alfred Douglass, Falmouth High School, Falmouth, MA
Andrea Frank, Mote Marine Laboratory, Sarasota, FL
Rosanne Fortner, Ohio State University, Columbus
Fredrick Glodis, Tisbury School, Vineyard Haven, MA
Roseanne Gross, Medfield Middle School, Medfield, MA
George Hussey, Falmouth High School, Falmouth, MA
Jim Johnson, Falmouth High School, Falmouth, MA
Barbara Klemm, University of Hawaii, Honolulu, HI
Mary Liepold, Washington, DC
John Paschal, West Charlotte High School, Charlotte, NC
Barbara Porter, EDS, Troy, MI
Don Salvatore, Boston Museum of Science, Boston, MA
Irwin Slesnick, Western Washington University, Bellingham, WA
Carole Slesnick, Bellingham, WA
Patricia Snowden, National Geographic Society, Washington, DC
Phyllis Whittington, Memphis Pink Palace Museum, Memphis, TN

Curriculum Developers and Lesson Reviewers

Mitchell Colgan, College of Charleston, Charleston, SC
Rosanne Fortner, Ohio State University, Columbus, OH
Tom Fritts, Smithsonian Institution, Washington, DC
Barbara Klemm, University of Hawaii, Honolulu, HI
James Marran, New Trier High School, Winnetka, IL
Cathy Offinger, Marquest Group, Woods Hole, MA
Patricia Robeson, Beltsville Academic Center, Beltsville, MD
Tom Simkin, Smithsonian Institution, Washington, DC
Irwin Slesnick, Western Washington University, Bellingham, WA
Robert Elder, Woods Hole Oceanographic Institution, Woods Hole, MA

Field Testers

NSTA is grateful to the teachers and the over 1,000 students who participated in the field test of this curriculum. Field testing was conducted in schools located in geographical areas surrounding four museums that are part of the JASON Project. The teachers are listed by museum area.

Mote Marine Laboratory, Sarasota, FL: Christine Evens, Wilkenson Elementary; Bernadette Dolan, McIntosh Middle School; National Geographic Explorers Hall, Washington, DC: Therese Johnston and Forrest Kennedy, George Washington Jr. High; Bonnie L. Bracey, Ashlawn Elementary; Clare Jayne, Falls Church High School; Peggy Little and Betty Grady, Hayfield Secondary School; Louvenia Gafney, Birney Elementary; Donna B. Smith, Walker Mill Middle School; Patricia Robeson, Beltsville Academic Center; Ontario Science Center, Toronto, Canada: Kerry Dupuis, Sacred Heart Catholic School; Rick Johnston, Pope John Paul II; Michael Murphy and Sandy Moher, St. Luke School; Joe Shultz and Paul Squirrel, Earl Haig School; Rochester Museum and Science Center: Joseph J. Priola, Brighton Middle School; Theodore P. Sawyko, Eastridge Jr. High School; Jim Armstrong, Klem Road North School; Darrel A. Dupra, Village Elementary School; Sherry Grimm, Hoover Drive Middle School; Marie Vayo, Allendale Columbia School; David Ferington and John Jungbluth, Brockport Central School; Jerry Hickey, Brookside Elementary; Kathy Giglio, Brighton High School.

Museum Education Coordinators

NSTA appreciates the assistance of the following museum representatives in developing the curriculum:

Jaré Cardinal, Rochester Museum & Science Center, Rochester, NY
Andrea Frank, Mote Marine Laboratory, Sarasota, FL
Phil Parfitt, Museum of Science and Industry, Chicago, IL
Phyllis Whittington, Memphis Pink Palace Museum, Memphis, TN
Judy Bazler, Lehigh University, Bethlehem, PA
Don Salvatore, Boston Museum of Science, Boston, MA

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Bill G. Aldridge, Executive Director, National Science Teachers Association, who provided the inspiration for the JASON Project Curriculum and serves as the Principal Investigator for the project

ABOUT THE CURRICULUM

Purpose

The JASON Curriculum Project materials have been developed by the National Science Teachers Association with assistance from the National Council for the Social Studies and funding from the National Science Foundation. The purpose of the materials is to prepare you and your students for an exploration on and around the Galápagos Islands via satellite transmission of live images and sound. You will be traveling with Dr. Robert Ballard, a crew of scientists, and the robot Jason Jr., or JJ, the "seeing eye" on the expedition. You will participate in the Galápagos expedition at a nearby museum, university, or other reception center, where you will enter a command station equipped with monitors receiving live transmissions from the Galápagos Islands.

This curriculum and the scientific expedition for which it prepares your students were designed to spark student interest in science, technology, and social studies. Through their participation, students may come to view these subjects as exciting, relevant fields of human activity which directly impact their lives. This taste of exploration may launch careers in oceanography or herpetology. Even more important, it may make future citizens in every field aware of the significant interplay among science, technology, and society, and their own responsibility for the global environment.

Components

The Galápagos JASON curriculum package contains 5 units, 25 lesson plans, and over 50 activities, along with teacher background material, student worksheets and readings, a resource listing, and a glossary. The package also contains a poster, a large map and numerous small ones, and complete materials for several games and simulations. Display the poster prominently in your classroom for the duration of this study. It is an integral part of the curriculum package and relates directly to several of the lessons.

Again this year the JASON curriculum materials have been compiled in one package for all grade levels 4 through 12. Activities were selected for their relevance to the JASON Project and their instructional value. Preview each unit to see what will work best for the grade level and the individual students you teach. Most of the activities were developed with middle grade students in mind, but the level of sophistication varies from lesson to lesson, and many contain adaptations for older and younger students. The Curriculum Overview provides a brief synopsis of each activity.

The package is divided into five units: Unit One, Introduction; Unit Two, Technology; Unit Three, Science; Unit Four, Social Studies; and Unit Five, Follow-Up. In spite of these divisions, however, the approach throughout is interdisciplinary. Students will do mathematics in the technology unit and environmental science in the social studies unit, while lessons in every unit draw on their skills in both decorative and language arts. The importance of interdisciplinary cooperation is a major theme of the JASON Project curriculum.

Lesson Format

The background text at the beginning of each unit surveys the lessons that follow and explains their relationship to the JASON Project. Each of the 25 lessons includes one or more activities, along with a rationale, learning objectives, a list of materials needed, and step-by-step procedures for the classroom. Masters containing various kinds of essential materials are named in the materials list and grouped at the end of the lesson. As you prepare to teach an activity, review the appropriate masters along with the lesson plan. The loose-leaf format of the curriculum package makes it easy to rearrange the pages as you use them.

Frequently the margin contains a "Teacher Take Note," a helpful hint for teaching that particular activity. Vocabulary words are also listed in the margin. Unless you know they are familiar to your students, write the vocabulary words on the board before beginning each lesson. If any unfamiliar word is not defined, check the curriculum glossary or your own reference materials.

More about Masters

The masters were designed to provide teacher background information; maps, charts, and illustrations for overhead viewing; and worksheets, data sheets, readings, and other materials for student use. Each master is identified by a unit and lesson number and a letter designating the order in which it occurs within the lesson. Those that are labeled Teacher Background Material are generally not intended as student handouts. Read them for your own enrichment, and use your judgment about sharing them with highly motivated students.

Some of the masters have more than one page. A few are used in more than one unit. Some have special instructions for duplicating, which are noted in the Teacher Preparation section at the beginning of the lesson plan. Masters that serve as student worksheets have the keys or answers to the worksheets on the back. Others have unrelated masters on the back. All masters are listed in order in the Table of Contents.

The curriculum resources at the end of the curriculum contain listings of books, magazine articles, and audiovisual aids. You will find it useful to consult the references cited in the bibliographies whenever you or your students are interested in greater detail on a particular topic. A Glossary, following the Curriculum Resources, includes all of the curriculum vocabulary.

Helpful Hints

- Don't be overwhelmed by the sheer size of this curriculum! There are many activities provided—too many for any one teacher to attempt—but they offer a selection from which you can pick and choose to suit your class's grade level, interests, and subject orientation.

- Require every student to keep a JASON Project notebook or journal, as suggested in the second lesson of Unit One. After each activity students can incorporate their handouts, lab data sheets, or notes they have taken in class. They can also use the notebooks for review before and after their visit to the downlink site.

- Carefully read the Lesson Overview to determine which lessons are most appropriate for your students. Then page through the activities themselves, and their accompanying masters, to make the final decision about what to teach.

- Familiarize your students with the metric system, even if you don't feel comfortable with it yet yourself. The metric system is used throughout these lessons, in keeping with NSTA policy. Approximate English equivalents are usually given in parentheses.

- And last, keep your students' interest in the lessons alive by reminding them of the adventure they are about to undertake. The land and water of the Galápagos Islands are one of the most exciting and unusual places on this Earth. Treat the activities as preparation for a real scientific expedition—for in fact, they are!

CURRICULUM OVERVIEW

Unit One: Introduction to the JASON Project

This is the core unit of the JASON Curriculum, and it should be taught in its entirety to provide the background for the telepresence experience. The three lessons in Unit I are a framework for the rest of the curriculum.

1.1 Jason Adventures Old and New

This lesson offers students a comparison of mythical explorations with real-life exploration. It reviews years one and two of the JASON Project explorations and provides biographical sketches of Robert Ballard and the 1991 project team. Students learn about the technology of the three submersibles Dr. Ballard uses in his work and then select the appropriate submersibles for specific scientific missions.

1.2 The Charles Darwin Research Station

The second lesson presents a geographical context for the Galápagos expedition. Students learn about the mission of the Darwin Research Station and begin their JASON journals.

1.3 Why the Galápagos?

Students learn about Charles Darwin and his trip to the Galápagos. They perform a taxonomy exercise to demonstrate their ability to discern classification details. Then they examine the relationship between local environmental problems and problems affecting the Galápagos.

Unit Two: Technology

These lessons will alert students to the wide range of technological innovations that make it possible for them to participate in live exploration.

2.1 Diving Technology

Students perform an activity which relates to the effects of buoyancy and weight on the robot and the scuba diver who will play key roles in the underwater exploration of the Galápagos. They set up a Cartesian diver demonstration to test their hypotheses about the relationship between pressure and volume.

2.2 Robotics

This lesson introduces students to applied robotics, elementary computer/robot programming, and the various uses of robots. Through a demonstration involving acceleration, inertia, and maneuverability, students learn why the robot Jason Jr. is the appropriate ROV for the Galápagos exploration.

2.3 Satellite Communications

This series of activities explains how information gets from a site underwater to a communications satellite and ultimately to the reception centers in less than a half a second. Students learn how parabolic dishes work and examine the elements of geosynchronous orbits.

2.4 JASON Transmission: Bringing It All Back Home

Students review basic wave theory and then manipulate images on cards to simulate the effect of live video. Younger students may make flip books of the blue-footed booby's dance. The last activity provides instructions for a class production of a network newscast.

Unit 3: Science

Earth science and life science are the focal points for the science unit. Lessons provide information on oceanography, plate tectonics, volcanoes, the El Niño event, as well as the flora and fauna of the Galápagos Islands and the waters that surround them.

3.1 The Galápagos Islands in Geological Time

In order to understand the vast span of geological time, students compare the time period of selected events in human history with events in the history and formation of the Earth.

3.2 Exploring the World's Oceans

Working with a map of the world, students calculate the percentage of the Earth's surface that is water. They use a sonar table and a mathematical formula to find the depth of various locations in the ocean and assemble puzzle pieces to gain an understanding of plate tectonics.

3.3 Building and Exploring an Island

Students observe a simulation of the way island chains such as the Galápagos are formed. They draw a profile map of Fernandina Island, and observe how much of a volcanic island is underwater. Students model two formations that result from different materials and different kinds of flow in volcanic eruptions.

3.4 Water on the Move: Ocean Currents on a Global Scale

Students perform an activity to create waves and a current on the surface of a body of water. They observe a demonstration of water mounding and leveling, and relate these processes to actual conditions in the Pacific Ocean. Next, they color-code a map to show the major currents affecting the Galápagos and interpret a diagram showing seasonal ocean conditions and upwellings. Students also learn about the dramatic temperature changes caused by El Niño and hypothesize about the effect of these changes on Galápagos life forms.

3.5 The Biodiversity of the Galápagos Islands

After reviewing the hydrologic cycle, students assign Galápagos plant species to their respective places on a model of rainfall zones. They observe differences in marine and land iguanas and hypothesize about the function of each adaptation. Students compare and contrast the traits of distinctive Galápagos land animals and relate specific organisms to their habitats.

3.6 Adaptation and Natural Selection

Students engage in a simulation that models the development of different bird species from a common ancestor and observe how random variations might increase an organism's chance of survival. In another activity, students sprout tomato seeds to illustrate a mutualistic relationship between two Galápagos species. Next, they assemble paper skeletons from rat bones such as might be found in pellets from the Galápagos barn owl.

3.7 Galápagos Islands Marine Food Web

Students learn about marine organisms, their locations in the Galápagos waters, and their feeding relationships. They also study the six trophic levels of Galápagos organisms and construct food web posters.

3.8 The Good News and the Bad News: Biological Impact of El Niño

Students observe tree trunk cross sections and diagrams of tortoise scutes, using proxy data to make inferences about the effects of environmental conditions on life forms. They analyze data about the effects of El Niño on animal populations to determine which species suffered and which seemed to benefit.

Unit 4. Social Studies

The importance of the Galápagos to the social sciences is largely in their geography. Most of the lessons in this unit have been structured on the five fundamental geography themes: location, place, human-environmental interaction, movement, and regions.

4.1 Where in the World?

This lesson reviews map use and basic geographical terms and concepts. Students find the relative and then the absolute locations of the sites involved in the Galápagos expedition.

4.2 Preparing for an Expedition to an Uninhabited Island

Students make preparations to visit the uninhabited island of Santiago, read an account of a scientist's visit, and decide what food, tools, and other equipment they should take with them.

4.3 Decision Making for the Galápagos

Students analyze economic and social choices that Ecuador faced in the 19th century with regard to the management of the Galápagos. Then they confront the issue of introduced species in the Galápagos, specifically the wild dogs, and make decisions about controlling their population.

4.4 Mapping Darwin's Route

Students plot the voyage of the *Beagle* on a map of the world in order to understand Darwin's visit to the Galápagos in the context of a round-the-world voyage.

4.5 Traveling with JJ

After tracing the route of the JASON expedition from Woods Hole to Guayaquil, Ecuador, students review what they have learned by playing a question-and-answer board game.

4.6 Growing Up in the Galápagos

A cultural inventory of life on Santa Cruz helps students compare their daily lives with those of their peers in the Galápagos. They discuss the concept of cultural regions and apply it to the islands.

4.7 The Galápagos Islands Tour Service

Students learn how their own region promotes tourism. Then, in cooperative work groups, they design a brochure to promote responsible tourism in the Galápagos. They debate the pros and cons of tourism for the Galápagos.

4.8 The Galápagos Islands in Time

Students read accounts of visits to the Galápagos over a span of 500 years. They role-play selected events and locate them on a chronology. They identify the events that have influenced the development of the Galápagos as an environmental refuge.

Unit 5. Follow-Up

The final unit of the curriculum includes student debriefing, project review, and an overview of the different careers involved in the JASON Project.

5.1 Debriefing and Discussion

Students discuss reactions to their telepresence experience at the downlink site, share data from their JASON journals, and make plans to continue their involvement with scientific discovery and environmental preservation.

5.2 Sharing What We Know

Students research a range of careers related to the JASON Project, then role-play specific careers in an international planning conference. They propose and evaluate alternative futures for the Galápagos Archipelago. In an alternate activity, students take the roles of museum personnel in planning an exhibit based on their JASON Project experience. Activities include research, design, construction, and public relations.

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THE GALÁPAGOS

JASON CURRICULUM

UNIT ONE

INTRODUCTION TO THE JASON PROJECT

BACKGROUND
Introduction to the JASON Project

Unit One provides an introduction to the 1991 JASON Project and a preview of the Galápagos Curriculum. The lessons in the introductory unit are critical to students' understanding of the scope of the project and are designed to whet their appetites for the expedition ahead.

In the first lesson, students learn about ROVs (Remotely Operated Vehicles) used in underwater exploration and compare real-life exploration with mythical exploration as related in the tale of Jason and the Argonauts. Biographies of Dr. Ballard and other expedition scientists present information on their previous experiences and their Galápagos assignments. A summary of the Mediterranean and Great Lakes JASON Projects provides a context for the 1991 exploration. A second activity in Lesson One describes the three submersibles used by Dr. Ballard and the particular technology of each. Using this information, students select the appropriate vehicles to be used on hypothetical expeditions.

Lesson Two provides information on the exploration site—the Galápagos Islands. Students learn about the mission of the Charles Darwin Research Station and debate conservation and economic issues. A checklist of flora and fauna found in the Galápagos prepares students for what they will see when they go on their Galápagos expedition.

The final lesson in the introductory unit emphasizes scientific observation and interpretation skills. Students read about the life of Charles Darwin and perform a classification activity using aluminum pull tabs. They also relate local environmental problems to those that threaten the unique ecosystem of the Galápagos Islands.

In working with the curriculum to prepare students for the expedition, teachers should emphasize the value of the scientific data which will be collected by the JASON explorers, both robotic and human, in the Galápagos. Students will accompany Dr. Ballard and his crew via telepresence and will be making discoveries simultaneously with the scientists.

JASON ADVENTURES OLD AND NEW

1.1

ACTIVITY ONE

Jasons in Myth and Science

Rationale

Dr. Robert Ballard and the other scientists at Woods Hole Oceanographic Institution (WHOI) have named some of their equipment after characters in the myth of Jason and the Argonauts. A comparison of mythical exploration with real life exploration provides background for the 1991 JASON Project.

Objectives

Students will:

Identify the elements of a myth.

Recognize the JASON Project logo.

Compare the voyage of the mythical Jason to Dr. Robert Ballard's explorations in the Mediterranean and Lake Ontario.

Materials

- Student copies of Master 1.1a, The Myth of Jason and the Argonauts
- Student copies of Master 1.1b, Robert D. Ballard Biographical Sketch
- Student copies of Master 1.1c, The JASON Project Adventure
- Student copies of Master 1.1d, Meet the 1991 Project Team (4 pages)
- Drawing paper and pencils or pens

Procedure

A. Introduction

Distribute Master 1.1a and give students time to read it. In a class discussion, ask students to name several elements of the JASON myth. List the elements on the chalkboard. (Myths are often based on actual events, but the events and characters have been exaggerated, distorted, or idealized in some way. Mythical characters and events are usually larger than life, and magic often plays a role in their outcome.)

VOCABULARY

Lo•go - a graphic or symbol that identifies a specific product or organization.

Myth - a traditional story, usually of unknown origin, that embodies beliefs of great significance to a culture.

R•O•V- Remotely Operated Vehicle, a robot such as JASON Jr.

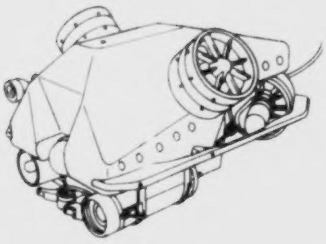
Sub•mer•si•ble - a type of ROV that is designed to operate underwater.

Tel•e•pres•ence - the sense of "being there" conveyed by satellite transmission of realtime exploration.

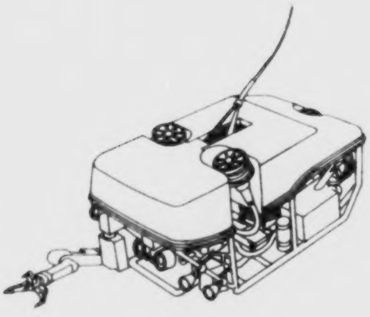
JASON PROJECT

TEACHER TAKE NOTE

All students need to read Master 1.1a or have it read to them. No student needs to read more than one of the other masters during class. You may, however, want to give each student a complete set for reading outside of class.



Jason Jr.



JASON

TEACHER TAKE NOTE

Activity Two in Lesson 3 of Unit Two invites students to compare the communications technology available to explorers of different eras.

B. Lesson Development

1. Distribute art materials and invite students to draw some of the characters in the Jason myth.

2. Divide the class into groups of three students each. Give each group one biography of Dr. Ballard (Master 1.1b), one JASON Project Adventure (Master 1.1c), and one or two of the profiles from Master 1.1d. (If your class has 18 students or more, give only one team member profile to each group.) Point out the JASON Project logo on Master 1.1c. Ask students what characteristics, if any, their drawings have in common with the image on the coin.

3. Allow time for students to read the material and discuss it briefly in their groups, then conduct a class discussion around one or more of the following questions:

- What qualities might Dr. Ballard and his crew have in common with Jason and the Argonauts?

- Why do you think the Woods Hole scientists chose the names *JASON*, *Jason Jr.*, *Argo*, and *Medea* for their ROVs?

- What were the goals of Dr. Ballard's JASON expeditions? What were the Argonauts' goals? Compare and contrast.

- Why does the myth tell so little about the individual members of Jason's team? (Mythical heroes like Jason succeed alone because of their superhuman or magical powers. Actual heroes usually succeed through skill and teamwork.)

- What were some of the dangers previous JASON Project crews encountered in the Mediterranean and Lake Ontario? How did each JASON Project crew overcome these problems? How did the mythical Jason overcome the problems that he encountered? Compare and contrast.

4. In the small groups, or as a homework assignment, have students create a myth-like story based on their expectations for the 1991 JASON Project expedition or one of the previous expeditions. Have them include themselves in the story as members of Dr. Ballard's crew.

C. Conclusion

Discuss how the mythical Jason's discoveries would have been communicated 3,000 years ago. How will the modern JASON's discoveries be communicated? What ancient technology would have guided the mythical Jason on his expedition? (sails, rudders, sighting by stars or other fixed points) What kind of technology will guide the modern JASON expedition? Tell students that they will learn more about modern technology in Unit Two of this curriculum.

Adaptations

For younger students

Show examples of logos other than the JASON Project logo. Have students describe logos with which they are familiar (commercial logos, school mascots, logos of sports teams). Discuss how these images characterize the products or groups that they represent. Challenge individuals to create personal logos that communicate their feelings about themselves and the things that are important to them.

For older students

Ask students to recall other stories they have heard, either traditional or contemporary, that have some of the elements of myth. These might include stories about people (Babe Ruth, Johnny Appleseed) or events (The First Thanksgiving, Custer's Last Stand, Woodstock). In each story, ask students to determine which elements appear to be facts and which have probably been distorted or elaborated. Broaden the discussion to the role myths play in expressing and developing a culture's image of itself.

JASON
CURRICULUM

ACTIVITY TWO

Appropriate Technology

Rationale

Dr. Ballard uses three different types of submersible vehicles when he explores the world underwater. Each has its own capabilities and limitations. Before each expedition, Dr. Ballard and his associates must decide which vehicle will be best suited for the tasks they hope to accomplish. They base these decisions on such criteria as the scientific goals of the mission, the communications goals of the mission (Is telepresence desirable?), the capabilities of the vehicle, and the cost in both equipment and personnel. Engineers at Woods Hole then adapt the chosen vehicle to perform specific functions during the expedition.

Objectives

Students will:

Identify the three submersible vehicles Dr. Ballard uses in his work.

Determine the capabilities and limitations of each vehicle.

Select appropriate submersibles for specific expeditions.

Materials

- Student copies of Master 1.1e, Three Submersibles (two pages)
- Student copies of Master 1.1f, You Make the Call

Procedure

A. Introduction

Distribute copies of Master 1.1e, Three Submersibles. Give students class time to read it or read it with them. Emphasize that all three vehicles are still used in active research. Explain that each has capabilities that may make it the best choice for a particular mission.

VOCABULARY

Al•tim•e•ter - an instrument for measuring altitude.

Co•ax•i•al ca•ble - a tube of electricity-conducting material surrounding a central conductor that is held in place by insulators, and used to transmit high frequency signals.

Fi•ber op•tic ca•ble - a bundle of hair-thin, flexible, transparent rods through which light is transmitted. Other forms of energy can be converted into light energy to be transmitted by fiber optic cable.

Knot - a measure of speed equivalent to one nautical mile (usually 1852 meters) per hour.

SHARPS (**S**onic **H**igh **A**ccuracy **R**anging and **P**ositioning **S**ystem) - a network of receivers with a computer that works by triangulation, using three known points to calculate an unknown location.

So•nar - a system for locating submerged objects by means of reflected sound waves.

Tel•e•pres•ence - the sense of being there conveyed by satellite transmission of realtime exploration.

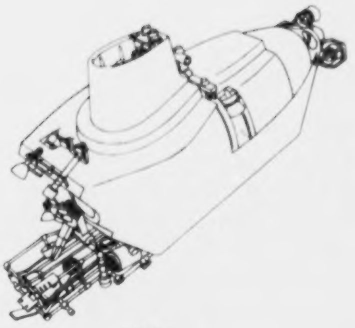
Twis•ted pair - an electrical cable consisting of two insulated conductors twisted together with a common wrap.

B. Lesson Development

1. Discuss the characteristics of the three submersibles. In a class discussion, compare and contrast the vehicles by focusing on the following considerations:

- types of projects for which each might be best suited
- speed, stability, maneuverability of each
- number of persons needed to operate the vehicle
- ease of getting the vehicle to the exploration site and lowering it into the water
- depth to which it can descend
- telepresence capability (video and audio hookups, speed of transmission)
- other technological elements that can be used with it, such as robotic arms and scraper baskets for collecting samples.

2. Distribute copies of Master 1.1f, You Make the Call. Using the elements they have identified and discussed, students should read about the possible expeditions and select the vehicle best suited for each mission.



Alvin

C. Conclusion

Ask students to discuss why they chose the vehicle they did in each case. Were their choices cost effective in terms of personnel? (Reinforce their thoughtful use of the data in the table. There are no right or wrong answers.)

Adaptations

For all students

1. Invite students to propose their own expedition sites and goals. Open a classroom debate on which vehicle would be best suited for each expedition.

2. Ask students to identify changes they might make in their chosen vehicle to adapt that vehicle for its task.

The Myth of Jason and the Argonauts

In the mythology of the western world, the first great explorer to sail the seas was the Greek hero Jason. Jason's mythical journey began over 3,000 years ago when he outfitted a ship to go in search of a golden fleece, the woolly hide of a golden ram. The fleece was in a distant land, hidden in a grove of trees and guarded by a dragon. Jason had to capture the fleece to gain possession of the kingdom that was rightfully his.

Jason called his ship the *Argo*, and his crew the *Argonauts* because they were *sailors* (Greek *nautes*) on the *Argo*. This band of hardy adventurers included the most famous of the Greek heroes. Hercules, the strongest man alive, was eager to join Jason. So was Peleus, the father of Achilles, and Orpheus, the masterful musician. The Argonauts sailed east across the Aegean, through the Dardanelles and the Bosporus, and into the Black Sea. The Black Sea was known to Greek sailors of that time as the "Unfriendly Sea" because of its fabled dangers.

Jason and his crew rescued an old man from the Harpies, hideous creatures with the bodies of birds and the heads of women who left a foul smell wherever they went. Then they found their way between moving cliffs that trapped other ships and crushed them. At last they arrived in Colchis, the land of the golden fleece. The king of Colchis welcomed his distinguished visitors, but he had no intention of giving up his golden treasure. He set impossible tasks for Jason to do to win the fleece. Fortunately for Jason, however, the king's daughter, Medea, fell in love with him. Medea was a powerful enchantress who used her magic to help Jason single-handedly overcome wild, fire-breathing bulls and an army of 1,000 soldiers. Then she lulled the dragon to sleep, helped Jason capture the fleece, and escaped with him to the ship. When her father sent an army after them she killed her own brother to help the Argonauts escape.

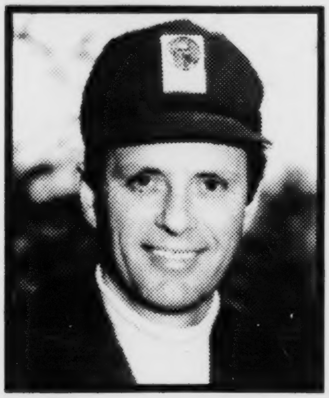
On the trip home, Jason and the Argonauts lost their way and wandered to the ends of the earth. Eventually, though, they did find their way back to Greece. These Argonauts were the first Greek explorers to travel to the Black Sea and return safely to their homeland.

After Jason became King of Greece he told the people about the fertile land he had seen along the Black Sea. Although Greece was a very beautiful country, its rocky soil made farming difficult, so life was hard for many people. Jason encouraged some of his subjects to leave Greece, colonize the area along the Black Sea, and trade with their homeland. Jason was a hero, then, for two reasons. Not only did he cross uncharted waters where others were afraid to go, but he also brought back knowledge that eventually made a difference in the lives of millions of people.

18

MASTER 1.1b

Biography of Robert D. Ballard



Robert Ballard is a Senior Scientist in the Ocean Engineering Department of the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, and Head of the Deep Submergence Laboratory. He is also Director of the Institution's Center for Marine Exploration and founder of the JASON Foundation for Education.

For as long as he can remember, Bob Ballard has been fascinated by the sea. When he was a boy in southern California, he collected sea shells and driftwood that were washed up on the beaches, and he studied the sea creatures that lived in tidal pools. As a teenager, he took up scuba diving and began to explore the underwater world. His favorite book was Jules Verne's *20,000 Leagues Under the Sea.* He received his undergraduate degree in geology and chemistry from the University of California.

While doing postgraduate work in marine geology at the University of Hawaii, he worked as a porpoise trainer at a nearby marine park and taught dolphins to dive through hoops and perform other tricks. In 1967, he entered the U.S. Navy and was assigned to the Deep Submergence Laboratory at Woods Hole where he has remained ever since.

Robert Ballard has led or participated in over 60 underwater expeditions, some of them involving the use of deep-diving *submersibles*. He made many of his dives in the Alvin, a small, three-person submarine. In 1973 and 1974, he explored the Mid-Atlantic Ridge, a huge underwater mountain range in the middle of the Atlantic Ocean. This ridge is part of a larger undersea range that extends 64,000 km (40,000 miles) around the globe.

In 1977, near the Galápagos Islands off the coast of Ecuador, Dr. Ballard and his crew discovered giant worms, some more than two and a half meters (eight feet) long, living inside white tubes and clustered around underwater hot springs. In 1979, he found black smokers off the coast of Baja, California. These underwater volcanoes erupt with hot fluids that shoot up from the sea floor through chimneys of lava.

In 1985, Dr. Ballard and his research team made their most famous discovery— the wreck of the R.M.S. *Titanic*. He and his colleagues designed a robot, the JASON Jr. (JJ), to enter the *Titanic* and photograph its interior. As a result of this successful venture, Dr. Ballard planned the JASON Project so that thousands of students could share the excitement of live exploration. In 1989 Dr. Ballard took approximately 200,000 students by telepresence to the bottom of the Mediterranean Sea, where they saw underwater volcanoes, artifacts, and the remains of ancient trading vessels. On the return trip he located the German battleship *Bismarck* off the coast of France. In 1990, year two of the JASON Project, Dr. Ballard, his crew, and JASON explored the wrecks of the *Hamilton* and *Scourge*, armed schooners that sank in Lake Ontario during the War of 1812.

Dr. Ballard has written many scientific articles and books about his explorations. He is the author of *Exploring Our Living Planet* and *The Discovery of the Titanic.* He has received many distinguished awards from universities, museums, scientific societies, and explorers' clubs. He has appeared in numerous television programs including three *National Geographic* specials.

Robert Ballard is committed to exploring the least-known portions of our planet—the regions that lie under water. According to Dr. Ballard, we are in the Lewis-and-Clark stage of exploration of these regions. He compares viewing the ocean floor with walking on the moon. In nearly 20 years of exploration, Robert Ballard has seen more of the ocean floor than anyone alive. When he's not exploring under water, he enjoys skiing, whitewater rafting, fishing, and watching his son play hockey.

The JASON Project Adventure

MASTER
1.1c

For two years, the JASON Project has taken thousands of students on fantastic underwater voyages. The remotely operated vehicle (ROV) JASON has photographed new life forms, remains of ancient Roman trade, and warships that sank in 1813.

Even after the expedition ends, the adventure continues. Every JASON expedition gathers large amounts of data. Researchers study and interpret that data for many years afterward. These two summaries will tell you something about the first two JASON Project expeditions and the research that has been done since.

The JASON Project 1989: Mediterranean Sea

Location: The Tyrrheniean Sea: Marsili Seamount (week 1); remains of the *Isis* (week 2).

Vehicle: JASON/Medea system, with robotic arm for collecting samples.

Research ship: *Star Hercules*.

Purpose: to investigate life near hydrothermal vents (week 1) and to explore the debris field left from an ancient Roman shipwreck (week 2).

Senior scientists

Dr. Robert Ballard, Woods Hole Oceanographic Institution (WHOI)
Dr. Anna McCann, Archaeologist

Observations

Week 1: Hot shimmering water, blue-green groupers, yellow sulfide deposits, deep-sea coral, starfish, Pholoe scaleworm, mineral chimneys.
Week 2: Amphorae, cooking pot, grinding stone.

JASON PROJECT

Early findings

Week 1: The samples collected were preserved onboard ship and sent to WHOI for study. Scientists there identified all the samples. None of these animals or sulfur samples were found to be specific to hydrothermal vent sites.

Week 2: A total of 43 objects were recovered and brought back to WHOI. All the amphorae have been desalinated (cleaned of salt deposits) and can now be exhibited. Three of the four wood fragments recovered from Isis can be carbon dated to around 400 AD. One piece was identified as white oak, a species found in Italy and Europe, but not in North Africa. The image on a coin found in the cooking pot was identified as that of Constantius II, the son of Constantine the Great. The coin is dated 355 AD. One final artifact, recovered by JASON pilot Martin Bowen, was a ceramic oil lamp approximately 12 cm long. It, too, was dated to the fourth century AD.

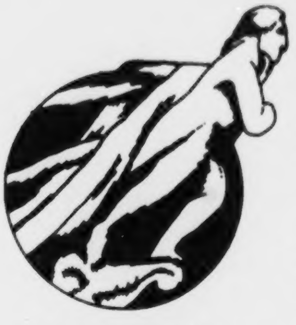
Unexpected event

The drama began even before the first show was telecast to the downlink sites across North America. During a routine test of the JASON/Argo system, waves caused by gale-force winds snapped the cable that powered the ROV and connected it to the research ship. JASON and Argo sank to the bottom of the Mediterranean. Quickly, Dr. Ballard and his crew swung into action. They unpacked a backup vehicle (named Medea after the woman who helped the mythical Jason in his expedition), fitted it with lights, cameras, and a giant grappling hook, and put it to work to locate the lost vehicles. After two attempts, Medea's pilot hooked JASON and Argo and hauled them back on board the *Star Hercules*. Dr. Ballard decided that Argo was too heavy to use in the expedition and substituted Medea in its place. After a careful check of both JASON and Medea, the crew was able to begin work in time for the first broadcast.

Anna McCann

The JASON Project, 1990: The Great Lakes

Location: Lake Ontario, near Port Dalhousie in the state of New York and Hamilton, Ontario, Canada.



Figurehead from the *Scourge*

Vehicle: JASON/Medea system.

Research barge: *Erie West*.

Date: May 1990.

Purpose: To map and investigate the condition of two wooden warships, *Hamilton* and *Scourge*, and perform a feasibility study to determine if they should be raised to the surface.

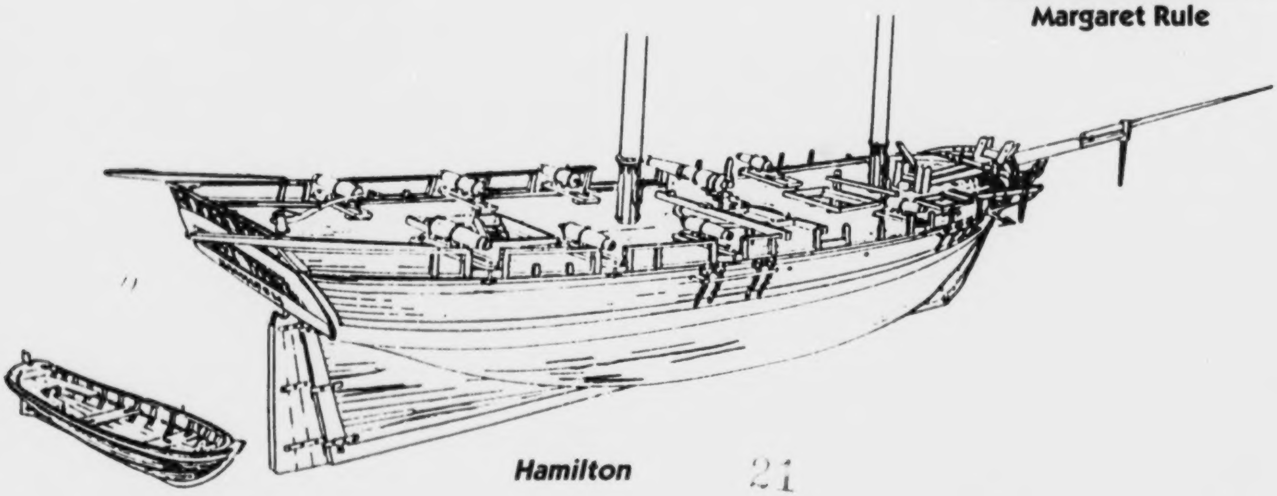
Senior scientists
Dr. Robert Ballard, WHOI
Dr. Margaret Rule, Archaeologist

Observations
Hamilton and *Scourge*, two warships that sank during a storm in August 1813, with their cutlasses, cannons, leather, windowpanes, rigging (rope), and grapeshot.

Early findings
From the computer mosaic imaging completed during the two-week investigation, Dr. Rule could determine that the two ships were in excellent condition. They can be raised to the surface after archaeologists further investigate the site and conservationists decide how best to preserve the wood. The final decision rests with the government of Canada and the city of Hamilton, but mapping was completed in days instead of years because of the JASON Project's sophisticated computer imaging technology.

Unexpected event
Like the Mediterranean voyage, the 1990 expedition was not all smooth sailing for Dr. Ballard and the JASON Project crew. Twice during the two-week cruise, sudden storms threatened the equipment and people onboard the Erie West. High winds and waves crashed across the deck, which was covered with work station vans and electrical equipment. On one morning of the program, video had to be substituted for the live feed, and Dr. Ballard conducted the live question-and-answer session from a phone booth on land. One storm even moved the barge out of position, endangering the sunken ships. Again, crew members worked together to minimize the damage. When the storm was over they were able to reposition the barge.

Margaret Rule



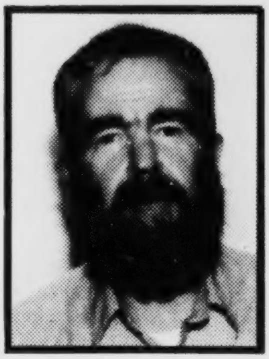
Hamilton

Meet the 1991 Project Team

MASTER
1.1d

Thomas Simkin

Geologist/Volcanologist
Director, Global Volcanism Program, Smithsonian Institution
Natural History Museum, Washington, DC



Education and Professional Training

Tom earned a B.S. degree in civil engineering from Swarthmore College. Unsure about what to do next, he accepted a commission with the U.S. Coast and Geodetic Survey to prepare nautical charts of the Pacific Northwest and Alaska. It was at this time that he discovered the fascination of geology. Later he earned a Ph.D. from Princeton University and a Postdoctoral Fellowship at the University of Chicago. His achievements include several books, *Volcanoes of the World, Krakatau 1883,* and *Global Volcanism 1975-1985*, and the map "This Dynamic Planet," which shows volcanoes, earthquakes, mountain ranges, and the movements of the Earth's plates by which they are formed.

Galápagos Assignment

Tom's duties at the Smithsonian involve him in the study of volcanoes worldwide. For twenty years he headed the Charles Darwin Foundation's Secretariat for the Americas. Tom's family has joined him on many trips to the Galápagos. His daughter Shona, a junior at Swarthmore, visited the islands when she was only 18 months old, and Adam, a tenth-grader, was born in Quito, Ecuador.

What do you like about your job?

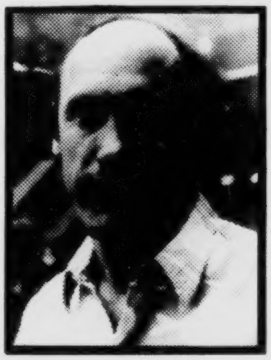
"In the '60s, I made twelve dives in Alvin to observe volcanoes on the ocean floor similar to the ones that form the Galápagos Islands. In 1968, I had the opportunity to observe the volcanic eruption and caldera collapse on Fernandina Island. This experience exposed me to the excitement of volcanoes, and since then I have worked exclusively on and around recent volcanoes. Since 1968, there have been eight eruptions on Fernandina, and I have made eight trips to the island. I find my work rewarding because every day I am learning new things about how the Earth works."

What would you like to tell students?

"Follow your natural curiosity. There's a lot we still don't know about how and why things happen; there are many, many unanswered questions. Looking for an answer doesn't mean you will find it instantly. It may take a lot of time, dedication, and hard work, but finding answers is very satisfying."

Jerry Wellington

Associate Professor of Biology/Marine Ecology
University of Houston



Education and Professional Training

Jerry was a Predoctoral Fellow at the Smithsonian Tropical Research Institute in Panama and earned his Ph.D. from the University of California at Santa Barbara. He participated as an aquanaut in the National Undersea Research Program in 1989, living for ten days with four other people in the undersea habitat Aquarius. Jerry studied the effects of ultraviolet light on reef-building corals at St. Croix in the U.S. Virgin Islands. He has researched corals in Belize, American Samoa, Enewetak in the Marshall Islands, Palau in the Caroline Islands, the Cocos Islands, and Antarctica. Jerry is the co-author of *Corals and Coral Reefs of the Galápagos Islands,* an advisor on marine affairs to the Charles Darwin Foundation in the Galápagos Islands, and an advisory editor for the *Marine Ecology Progress Series*, an international journal based in Germany.

Galápagos Assignment

Jerry, along with JJ, will be a key underwater player in the Galápagos expedition. He will direct the offshore marine biology site. Camera crew with video equipment will accompany him when he dives. Jerry's scuba gear is outfitted with two-way audio and one-way video feeds so students at the downlink sites can see and hear what goes on underwater.

What do you like about your job?

"My interest in the Galápagos began in 1973 when I was sent there as a Peace Corps Volunteer and wound up making a survey of marine resources for the Galápagos National Park Service and the Charles Darwin Foundation. This two-year survey eventually led to the establishment of the largest marine reserve in the world in the waters around the archipelago. I feel a tremendous obligation to share the excitement of this undersea world with students. In the JASON Project, students and scientists have a rare opportunity to work hand in hand on an important environmental issue."

What would you like to tell students?

"Being a scientist means having a passion for learning and a dedication to finding out. It is not a part time activity. I would urge students to develop a tremendous curiosity about the world in which they live. Our natural world is being diminished by human activities. It will take the dedication of scientists and the cooperation of informed citizens to preserve endangered natural communities."

Catherine Offinger

Logistics Coordinator
JASON Project Manager for MARQUEST Group, Inc.

Education and Professional Training

Cathy earned her B.A. from Skidmore College. She began working with Dr. Ballard in 1975, and has taken part in many of his expeditions, including the discovery of the *Titanic* and the *Bismarck*. In 1976, Cathy travelled to the Cayman Trough, where 35-mm color film was first processed at sea. Cathy works as a data logger and navigator as well as an on-site logistics coordinator on many of Dr. Ballard's expeditions.

Galápagos Assignment

Cathy has helped the groups involved with the JASON Project communicate with each other and with the general public. She made all the arrangements for transporting the huge vans that carry supplies for the JASON expeditions. She has also assisted in securing permission from the customs authorities for moving the expedition's people and supplies across national borders. She arranged insurance for the expedition, and searched for a diving doctor to join the crew in the Galápagos. Cathy initiated *The JASON Foundation Network News*, a newsletter for JASON Project partners.

What do you like about your job?

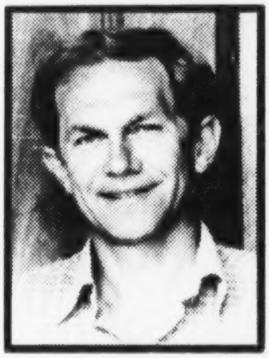
"I love the challenge of bringing a difficult project to a successful conclusion. Working with the JASON Foundation for Education is particularly wonderful for me because I can share all the excitement of the expeditions with my nine-year-old daughter Heidi. I'm delighted at the opportunity to teach my own child as well as thousands of other students."

What would you like to tell students?

"Cultivate a variety of interests; work hard at what you start; stay in school. Whatever team you're on, try to appreciate the hard work of your fellow team members. Be cheerful when others seem down. Challenge yourself, and experience as much as possible."

Haraldur Sigurdsson

Professor of Oceanography
University of Rhode Island



Education and Professional Training

Haraldur earned his B.S. in geology at the Queen's University of Belfast, Northern Ireland, and his Ph.D. in petrology and geology at Durham University in England. Haraldur is a geologist and a teacher who specializes in oceanography and volcanic activity worldwide. He travels widely to study volcanoes and other phenomena in the field and to talk about them at scientific meetings. He is fascinated with ancient volcanoes as well as modern ones; a recent publication dealt with the eruption of Vesuvius in AD 79.

Galápagos Assignment

Haraldur is a certified explorer; he was elected to the prestigious Explorers Club in 1979. In 1989 he made two dives in a submersible, exploring a submarine volcano in the Caribbean called Kick-'em Jenny, and in 1990 he made 59 dives around Krakatau with scuba gear. His knowledge and experience will make him a valuable member of the JASON team.

What do you like about your job?

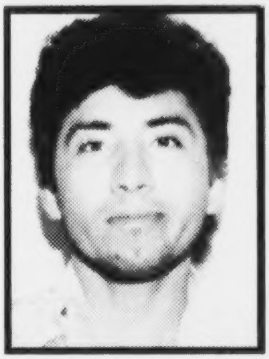
"I lived with volcanoes as a young boy growing up in Iceland. I became curious about how they worked, and I have never stopped wondering about this marvelous phenomenon. The fishing trips and camping and climbing expeditions that filled my boyhood have given way to scientific expeditions. My wife Jean travels with me whenever she can. We recently spent several months in Indonesia together."

What would you like to tell students?

"Never stop asking questions about how the world around you works. We owe most of our knowledge about the Earth and space to the natural curiosity of individuals. Let yourself go, let your curiosity run your life. Get out into the world and experience it hands-on."

Carlos Valle

Naturalist/Ph.D. Candidate
Department of Ecology and Evolutionary Biology
Princeton University



Education and Professional Training

Carlos Valle moved to the Galápagos when he was four years old. Growing up in the Islands, he became fascinated with the animal life, which was so tame that finches would land on his table and share a plate of rice with him. Although his father tried to talk him into becoming a doctor or a politician, Carlos decided at an early age that he would become a biologist. He earned a B.S. degree in biological science from Catholic University in Quito, Ecuador. His undergraduate thesis, published in Spanish, dealt with the frigate bird of the Galápagos. During his undergraduate years, Carlos received a grant from the Charles Darwin Research Station to spend 1983-84 working and learning at the station as an ornithologist. He later worked as a free-lance naturalist guide in the Galápagos. In 1987 he came to the U.S. and worked with a group of biologists at Point Reyes Bird Observatory in San Francisco. Now Carlos spends six months of the year at Princeton University and six months in the field in the Galápagos. His current area of study is cormorants.

Galápagos Assignment

The site of the 1991 JASON Project is the area that Carlos has been studying for years. Because he knows the area so well, he will serve as a general advisor to the project. During the first week of the JASON broadcast Carlos will be on-camera helping to identify some of the Galápagos birds. While at the expedition site, he will also resume his own research on cormorants.

What do you like about your job?

"I most enjoy the opportunity to be surrounded by nature. (I appreciate the city too, but only after I've been out in the field living in a tent for three or four months.) Growing up in the Galápagos as I did, I developed a great love for the animals there. Becoming a biologist allowed me to study my favorite creatures, the birds. After I receive my doctorate, I would like to teach in the United States for half the year and continue my research in the Galápagos for the other half of the year."

What would you like to tell students?

"On your trip via telepresence to the Galápagos, observe closely. Even if you are not planning to be a biologist, appreciate everything you see of a place controlled by nature, with minimal human intervention. And, if you ever get the opportunity to come to the Galápagos in person—take it!"

Thomas Fritts

Research Biologist
Chief, Biological Survey Group
U.S. Fish and Wildlife Service
Smithsonian Institution, Washington, DC

Education and Professional Training

Tom earned his Ph.D. in biology from the University of Kansas. He has studied and written about lizards in Mexico and high altitude lizards in the Andes. This interest in reptiles soon led him to the Galápagos Islands to study both the giant tortoises and the marine turtles. In addition to reptiles in the Galápagos, Tom is also researching problems caused by an introduced snake in Guam.

Galápagos Assignment

Tom is the editor of the *Noticias Galápagos*, the major publication of the Darwin Foundation. He also serves as an advisor to the JASON project and assisted in developing the curriculum's biology lessons.

What do you like about your job?

"I spent my early years growing up in the Midwest, where I had ample opportunities to explore the outdoors and encounter wildlife. I feel incredibly lucky to be able to make a career out of learning and teaching about wildlife."

What would you like to tell students?

"Not all scientists travel to remote areas or deal with large, unusual animals. But the animals outside your back door and in your local park also exhibit complex adaptations to their environment, and are well worth studying."

Linda Jean Cayot

Head of Herpetology
Charles Darwin Research Station

Education and Professional Training

Linda earned a B.S. and an M.S. in wildlife biology from Colorado State University. She earned her doctorate from Syracuse University with a dissertation on the ecology of giant tortoises in the Galápagos.

Galápagos Assignment

Linda has been in charge of reptile programs at the Darwin Station since 1988. She works closely with the Galápagos National Park Service in reptile management programs that include the breeding and rearing of giant tortoises and land iguanas and their eventual return to their original islands. She also supervises the research of Ecuadorian university students and coordinates with visiting scientists who come to study the reptiles of the Galápagos.

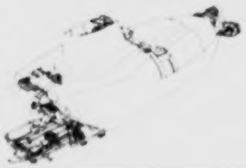
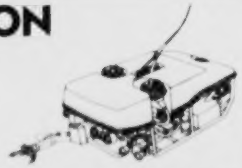
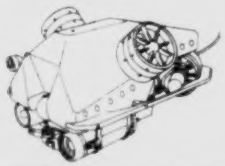
What do you like about your job?

"It was hard to leave the Islands in 1983, when I finished my two and a half years of doctoral research on the tortoises. When the opportunity to return arose, in 1988, I jumped at the chance. It has given me great satisfaction to not only study the tortoises, but also work at solving some of the serious problems they and the other reptiles face today. I also enjoy working with the people of the Galápagos, especially the dedicated park wardens, in our common effort to preserve the Islands."

What would you like to tell students?

"Pursue your interests, whatever they may be, and have confidence in yourselves. Our planet is a mess. Only with each one of us striving to take care of it and using our gifts to make it better will we be able to move into the 21st century with the natural world intact."

Three Submersibles

Features of Submersibles	**Alvin** 	**JASON** 	**Jason Jr. (JJ)** 
Type	accommodates crew	ROV (remotely operated vehicle)	ROV
Operators required	1 pilot and 2 scientific observers onboard plus support ship crew	8–11 (pilot, surface control, navigation, and imaging) on the support ship	3, including 1 pilot on the support ship
Operating costs			
Vehicle (per day)	$8,700	$8,900	$3,200
Support (per day)	$16,500 (*Atlantis II*)	$7,000 (any large ship)	$500–1,000
Prep fee (one time fee)	$25,000	$15,700	$3,400
Size	7.6 m long x 3.9 m high x 2.8 m wide	2.44 m long x 1.22 m high x 1.22 m wide	0.71 m long x 0.51 m high x 0.51 m wide
Weight	17,300 kg	1088 kg	100 kg
Number of dives	1,716 through 1989	50	20
Full speed	1.5 knots (1 knot cruising)	1.5 knots	1.2 knots
Endurance	72 hours (normal dive is 6-10 hours)	constant (no theoretical limit)	constant (no theoretical limit)
Depth capacity	4,000 m	6,100 m	6,660 m
Construction	syntactic foam, aluminum frame, titanium passenger sphere, can be positively or negatively buoyant	syntactic foam, titanium casings, tubular aluminum frame, slight positive buoyancy	syntactic foam, titanium casing, aluminum frame, slight positive buoyancy
Propulsion	1 large stern propeller, 2 small side-lift propellers	7 thrusters	4 thrusters
Navigation	gyro compass, magnetic compass, sonar, echo sounder, 5 viewpoints (windows)	SHARPS system, magnetic compass, gyro compass, pressure sensor, altimeter	gyro compass, SHARPS system
Electrical power	3 banks of lead-acid batteries, 60 and 30 DC systems. 40.5 kwh total	electrical cable from ARGO/support ship, 18 amps at 120 volts, three-phase AC	2 power conductor cables, 5 amps at 120 volts maximum
Communications	closed circuit TV system, sonar telephone (voice or code), marine band (VHF) radio telephone	fiber optic cable	twisted pair for data and control, coaxial cable for video

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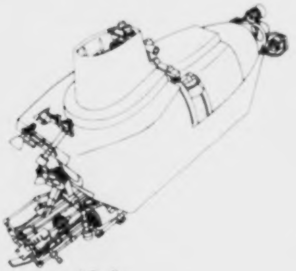
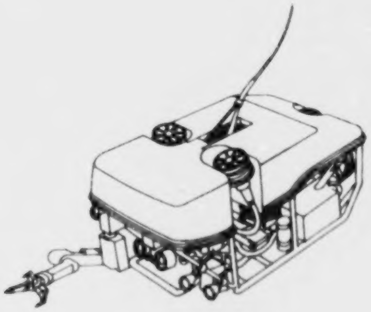
Other features	remotely controlled mechanical arms and sampling equipment, underwater cameras and associated lighting equipment, data logging system, water temperature monitor, current speed meter, precision depth indicator	remotely controlled mechanical arms and sampling equipment, forward scanning sonar, 2 side sonars, 3 video cameras (high resolution color and 35-mm), and associated lighting equipment, mission-specific sensors	scraper basket for collecting equipment, high resolution video and 35-mm still cameras (1 each) and associated lighting equipment
Advantages	not tethered to ship; allows unimpeded motion and personal observation	viewing capabilities limited only by its own size; telepresence potential; can remain underwater 24 hours per day; stable craft, exceptionally good for mapping projects	lightweight, quick, very maneuverable, not labor intensive, easily launched and retrieved, provides telepresence, does not require sled
Disadvantages	requires a support ship, limited viewing ability, limited research time, needs crane for launch and retrieval, puts humans at risk, expensive to operate	heavy, slow, limited maneuverability, expensive to operate, labor intensive for peak performance, needs sled system (ARGO) to maintain stability, needs sled for launch and retrieval	limited room for mounted cameras and data collection equipment, limited sample retrieval ability, less stable in water than other submersibles, less clear video image for satellite
History	developed at Woods Hole Oceanographic Institution by Allyn Vine (for whom it was named) in 1964; designed to require minimal assistance from large vessels; normally used with support ship, *Atlantis II*, for launch and recovery	developed at Woods Hole Oceanographic Institution; funded in part by U.S. Navy; first used in the 1989 JASON Project expedition to the Mediterranean	developed at Woods Hole Oceanographic Institution; funded in part by U.S. Navy; prototype for larger JASON model; gained fame during the *Titanic* exploration
Expeditions	used by Dr. Ballard in his trips to the Galápagos Islands in 1977 and 1979 and in his *Titanic* search and discovery in 1986; still actively used, and now makes approximately 100 dives per year	Mediterranean, Lake Ontario, Pacific and Atlantic Oceans	*Titanic* expedition 1986, various short trips

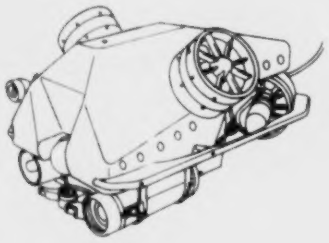
You Make the Call

MASTER
1.1f

You are the senior scientist at an oceanographic research institute's Deep Submergence Laboratory, and have been asked to participate in a number of research expeditions. For each mission in the list that follows, you must choose one of the laboratory's three submersible vehicles. In making your decisions, be sure to consider the cost in equipment and personnel, the vehicle's capabilities, your scientific goals, and your communications goal for each mission. The vehicles available to you are:


Alvin


JASON


Jason Jr.

1. The U.S. Navy wants to use a submersible to find a hydrogen bomb lost in the Atlantic in a plane crash. The navy will fund the mission.

I would use: ________________ *because* ____.

2. A national group of scientists wants to investigate a fault zone off the coast of Southern California. You will be mapping the entire area for later analysis. The National Science Foundation will fund the mission.

I would use: ________________ *because* ____.

3. You have been hired by the National Science Teachers Association and the National Council for Social Studies to explore the *Lusitania*, an ocean-going vessel that sank near Ireland in 1915. You will be looking at both the inside and the outside of the ship. A federal education grant will fund the project.

I would use: ________________ *because* ____.

4. Scientists at your oceanographic institute want to reinvestigate vent sites at Marsili Seamount in the Mediterranean Sea. The institute will pay for the expedition.

I would use: ________________ *because* ____.

5. A group of archaeologists would like to investigate and document a shallow underwater site, with the possibility of retrieving samples. Funding is uncertain at the time of request.

I would use: ________________ *because* ____.

6. You will be investigating the natural environment of an important island group in the Pacific Ocean. You will be broadcasting the expedition from six onland and underwater sites. You will be using a submersible to follow animal life in several different areas around the island. You must find funding for the project.

I would use: ________________ *because* ____.

THE CHARLES DARWIN RESEARCH STATION

1.2

Rationale

The JASON exploration site is the Galápagos Islands, a setting that provides students opportunities to learn about both scientific exploration and global cooperation. The Charles Darwin Research Station on the island of Santa Cruz operates under the auspices of the Ecuadorian Government, UNESCO, and the International Union for the Conservation of Nature and Natural Resources.

Objectives

Students will:

Locate the Galápagos Islands on a world map and identify specific locations in the Galápagos region.

Find the Darwin Research Station on a map and describe its mission.

Begin their JASON journals.

Materials

- JASON Project poster
- Globe, wall map of the world, or Master 1.2a, World Map
- Overhead projector
- Master 1.2b, Galápagos Map
- Rulers or meter sticks for measuring desks
- Master 1.2c, Teacher Background Reading, The Charles Darwin Foundation and Issues in Preservation (on back)
- Student copies of Master 1.2d, A Research Station for the World
- Student journals (new notebooks and binders to be used only for this project)
- Student copies of Master 1.2e, The JASON Project Partners
- Student copies of Master 1.2f, Checklist for the Expedition
- Transparencies made from Master 1.2f, Checklist for the Expedition (for expedition review)
- Articles and books on the Galápagos (See unit bibliography.)
- Galápagos Map included within the curriculum

VOCABULARY

Ar•chi•pel•a•go - a group of islands sharing common physical and locational characteristics.

Charles Darwin

TEACHER TAKE NOTE

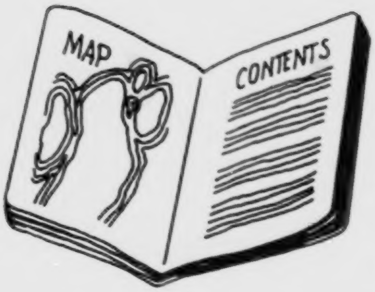
Teacher background readings are not intended as handouts for elementary or middle level students. Use your own judgement about making copies for older students.

JASON
JOURNAL

Teacher Preparation

Read the teacher background piece, Master 1.2c, and decide on the best way to present the information to your class.

Several days before you plan to begin this lesson, assign students to bring a new notebook to school. This notebook will be their project journal, reserved for this purpose only.



A. Introduction

Display the 1991 JASON Project poster and encourage students to comment on what they see. Then gather the class around a world map or globe, or project Master 1.2a, World Map. Encourage students to point out the equator and discuss its significance. Then ask them to locate the country of Ecuador. Ask: Does anyone know what *Ecuador* means in Spanish? (equator) Have a student trace the equator with one finger as it goes through Ecuador and out into the Pacific Ocean, then find and name the group of islands that lies 1000 kilometers (600 miles) west of the Ecuadorian coast. (the Galápagos)

Project Master 1.2b, the Galápagos map. Ask if anyone knows what *Galápagos* means. Then on the JASON Project poster, point out the giant tortoise for which the islands are named. Explain that the tortoises can grow to 1.5 m (about 5 feet) in length and weigh as much as 230 kg (500 pounds). Have students measure their desks and compare that size to the size of the tortoises.

TEACHER TAKE NOTE

If you have Spanish-speaking students, ask for their help in pronouncing the names of the islands.

Again call their attention to the Galápagos map, and review the names of the islands in the Galápagos Archipelago with the students.

B. Lesson Development

TEACHER TAKE NOTE

The expedition camera sites marked on Master 1.2b were fixed when the curriculum was printed. Sites may be subject to change, however.

1. Point out the sites the students will visit by telepresence. Ask a volunteer to find Santa Cruz Island where the Darwin Research Station is located.

2. Distribute copies of Master 1.2d, A Research Station for the World. Read it with the class or allow time for silent reading, then answer any general questions students may have.

3. Present the main points from the issues section of the teacher background reading. Divide the students into four groups to debate some of the challenges that confront a foundation with a conservation mandate.

Group 1. *Charles Darwin Foundation:* Ecuadorian officials, scientists, businesspeople, and educators; along with officials, scientists, businesspeople, and educators from around the world.

Group 2. *Charles Darwin Research Station:* Scientists, laboratory and office workers, mechanics, university students working on projects in the Galápagos.

Group 3. *Galápagos National Park Service* (under the Ecuadorian Ministry of Agriculture): park rangers and teachers.

Group 4. *The Local Business Community*: representatives of tourist agencies, land developers, and shopkeepers in the Galápagos.

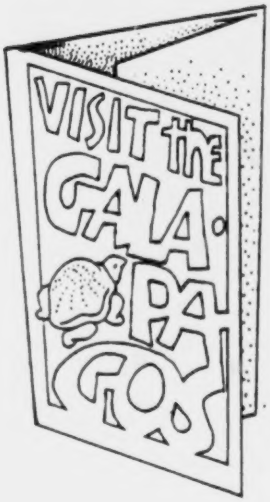
4. Assign roles, or ask students to choose a role from those suggested for their group and to think about one or more of the issues from that person's point of view. Encourage students to reach consensus on the best way to resolve the issues. Pose these questions in turn:

- Should people who lived on the islands before the park was formed be restricted in their use of the islands' natural resources?

- What are the positive and negative effects of tourism?

- Should visitors be allowed to tour all parts of the islands?

- What is the value of preserving native species?



C. Conclusion

Tell students that they may have a chance to debate some of these issues again in Unit 5, after their visit to the museum or other downlink site. Explain that by then they will have learned about other organizations that contribute, through the JASON Project, to teaching about the importance of the Galápagos. Distribute Master 1.2e, The JASON Project Partners, and go over it with the class.

Distribute the checklists, copies of Master 1.2f, and tell students that they will use them when they go to the downlink site. Direct students to take out their JASON journals and insert the handouts from today's lesson. Explain that they will receive worksheets and readings throughout the project, and that they can add pictures, articles, and ideas of their own as time goes on. Relate the journal to Charles Darwin's *Beagle* Log and the record-keeping of other naturalists. Encourage students to include their own thoughts and questions.

With each lesson, ask students to respond to the following questions and to include the responses in their journals:

-What new fact or facts did you learn?

-How do you feel about it/them?

-What questions do you still have?

Explain to the students that they will refer to their journals throughout the project and before and after they go to the downlink site.

TEACHER TAKE NOTE

Make it easy for students to keep their JASON Project handouts in their journals by punching the sheets with a three-ring hole punch before each lesson.

Expedition Review

Review the sites of the JASON expedition on the map and update students with new information if necessary. (You will be notified by your site coordinator if the locations change.) Project the checklist and point out what the students will be looking for when they begin their expedition with Dr. Ballard and JJ.

Adaptations

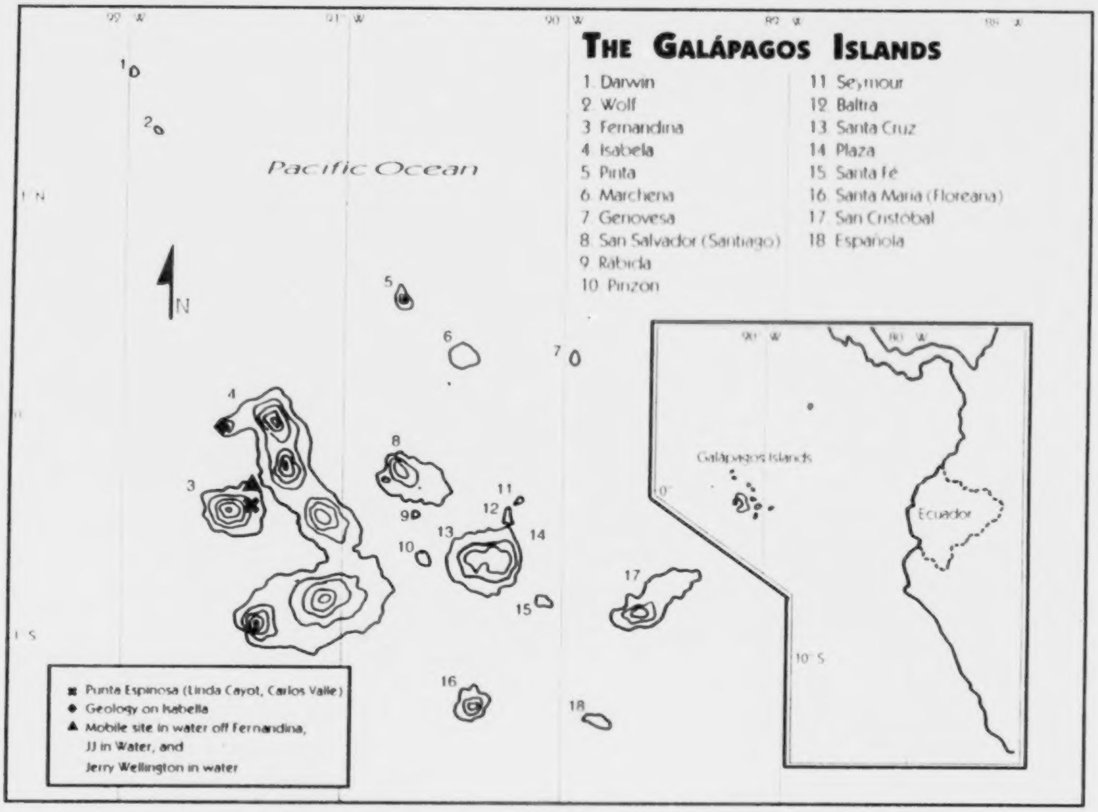
For younger students

Provide pictures of animals found in the Galápagos that children may draw and color for their journals. (You may duplicate the poster or see the Science Unit, Lessons 3.5 and 3.7, for illustrations.) Challenge students to find pictures of some of the other animals named in the checklists.

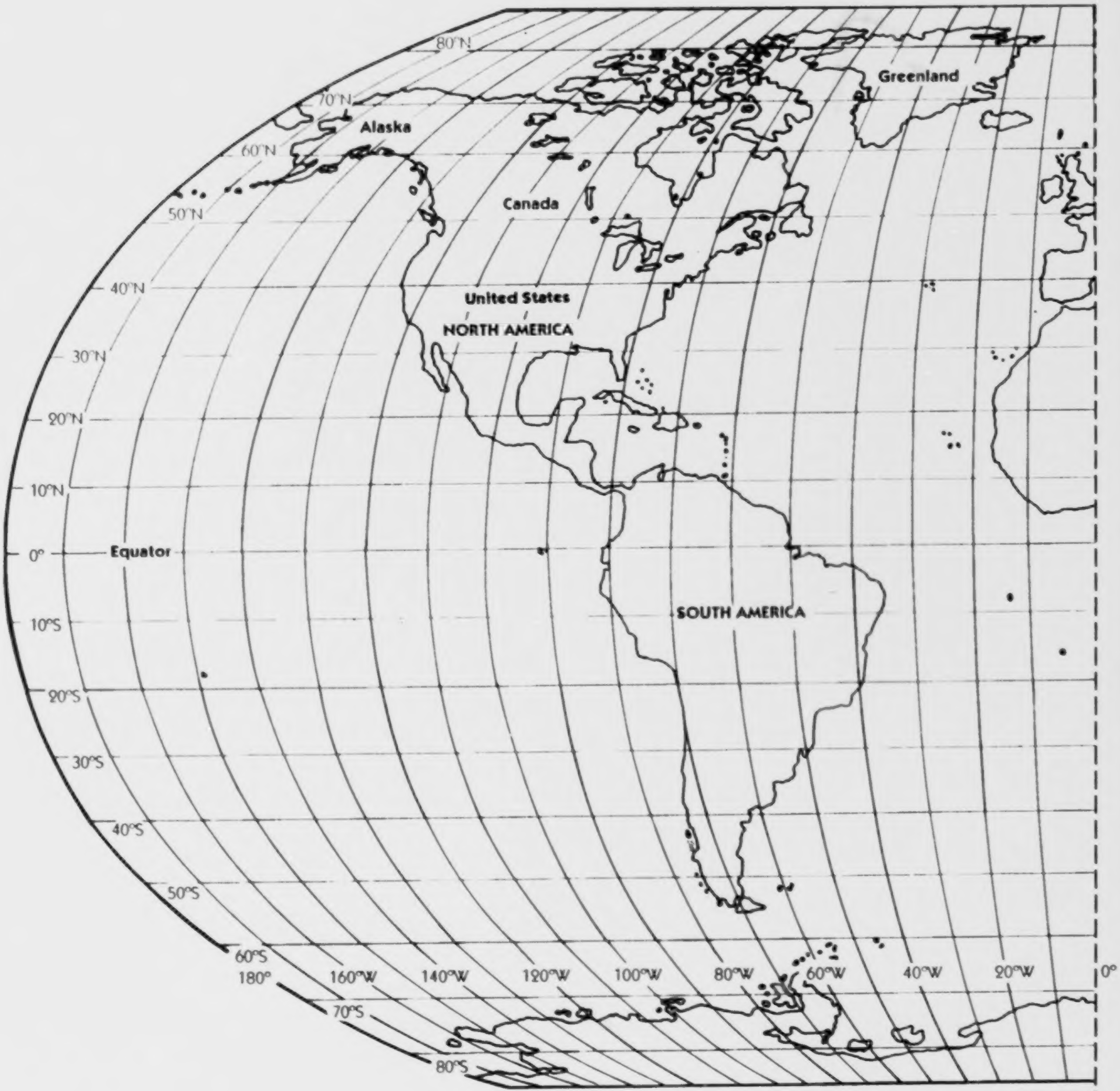
For older students

1. Ask students to read and report on a book or article about Darwin and/or the Galápagos. Motivated students may choose to study one aspect of the islands in depth.

2. Invite students who know Spanish to write to the Ecuadorian government for information about the islands and to later share what they learn.


THE GALÁPAGOS ISLANDS
1. Darwin
2. Wolf
3. Fernandina
4. Isabela
5. Pinta
6. Marchena
7. Genovesa
8. San Salvador (Santiago)
9. Rábida
10. Pinzon
11. Seymour
12. Baltra
13. Santa Cruz
14. Plaza
15. Santa Fé
16. Santa Maria (Floreana)
17. San Cristobal
18. Española
Pacific Ocean
N
92° W
91° W
90° W
1° N
1° S
Galápagos Islands
Ecuador
90° W
80° W
0°
10° S
✖ Punta Espinosa (Linda Cayot, Carlos Valle)
◆ Geology on Isabella
▲ Mobile site in water off Fernandina, JJ in Water, and Jerry Wellington in water

World Map with Coordinates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140°W
120°W
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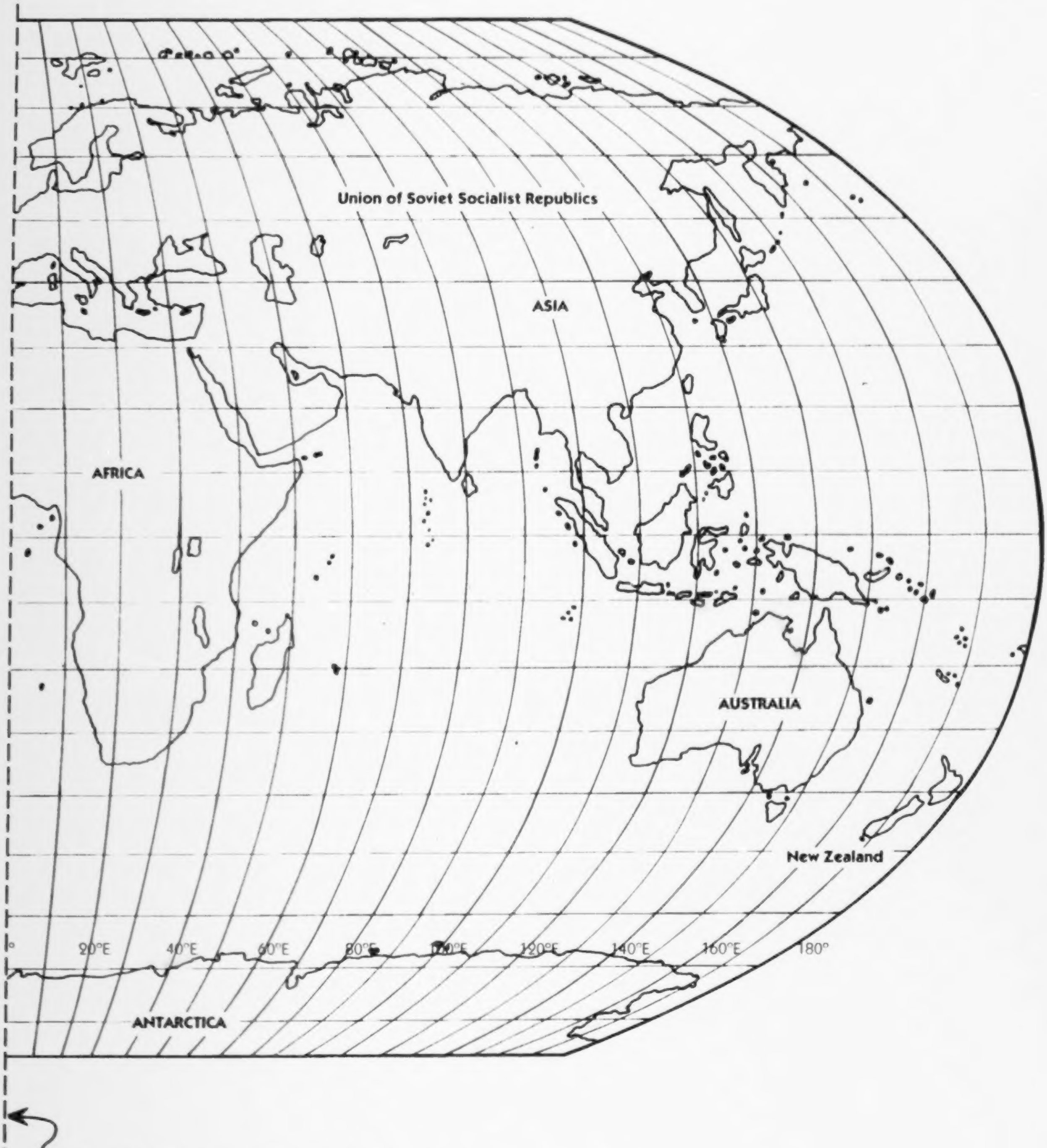
Canada
Greenland
United States
NORTH AMERICA
SOUTH AMERICA

35


Union of Soviet Socialist Republics
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AFRICA
AUSTRALIA
New Zealand
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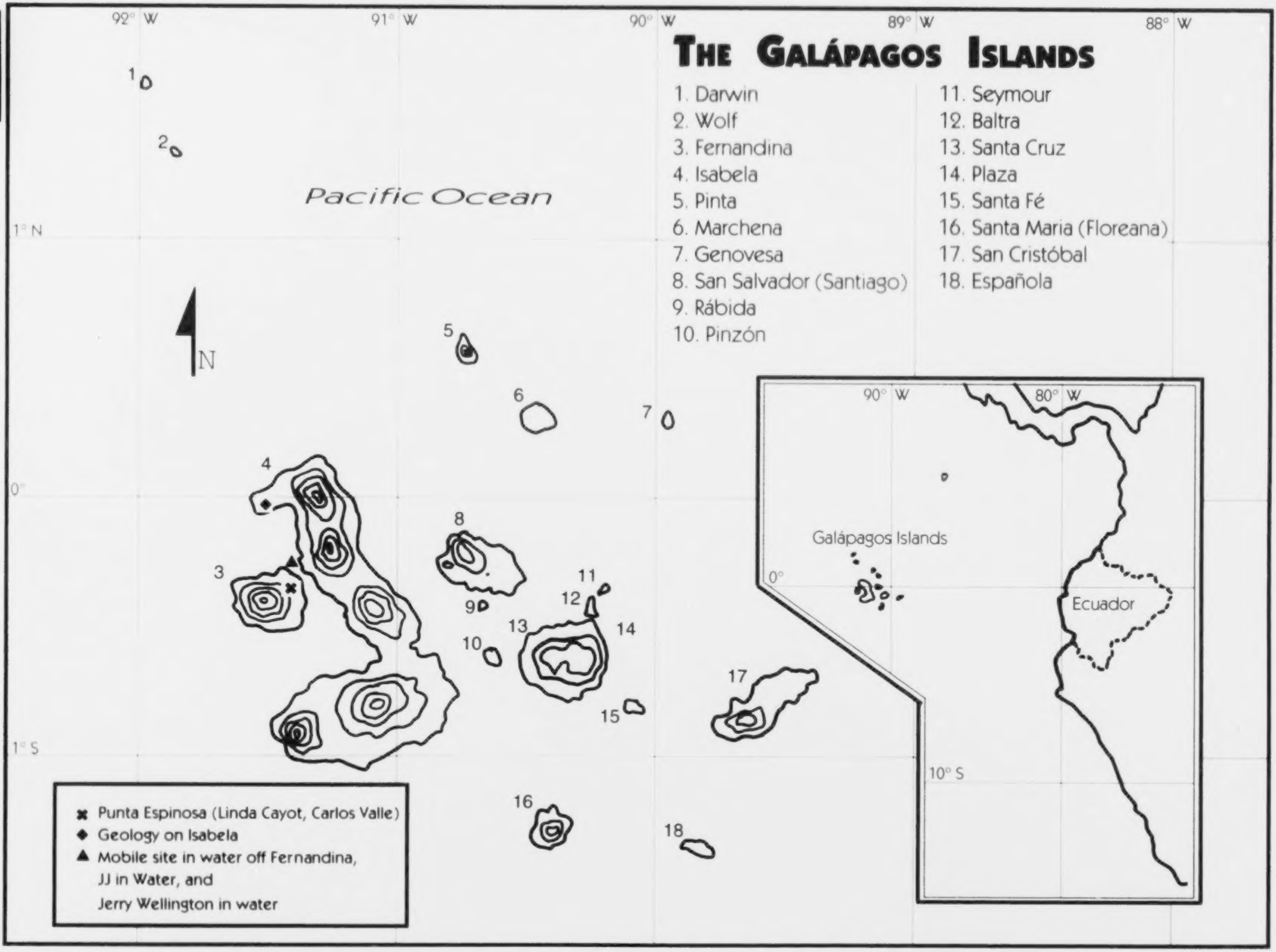
140°E
160°E
180°

Cut along dashed line and tape to other sheet

36

THE GALÁPAGOS ISLANDS

1. Darwin
2. Wolf
3. Fernandina
4. Isabela
5. Pinta
6. Marchena
7. Genovesa
8. San Salvador (Santiago)
9. Rábida
10. Pinzón
11. Seymour
12. Baltra
13. Santa Cruz
14. Plaza
15. Santa Fé
16. Santa Maria (Floreana)
17. San Cristóbal
18. Española


92° W
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Pacific Ocean
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90° W
80° W
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10° S
Galápagos Islands
Ecuador

✖ Punta Espinosa (Linda Cayot, Carlos Valle)
◆ Geology on Isabela
▲ Mobile site in water off Fernandina,
JJ in Water, and
Jerry Wellington in water

MASTER 1.2c

Teacher Background Reading

The Charles Darwin Foundation and Research Station

Many people have worked together to preserve the unique habitat of the Galápagos Archipelago. In 1959, 100 years after the publication of Charles Darwin's *Origin of Species*, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and the International Union for the Conservation of Nature established the Charles Darwin Foundation for the Galápagos Isles. That same year, the Government of Ecuador declared the islands a national park and created *Servicio Parque Nacional Galápagos* (The Galápagos National Park Service).

Charles Darwin at age 40

The Charles Darwin Foundation (CDF) is governed by a 34-member executive council whose role is similar to that of a board of directors. Half of the members represent the major Ecuadorian governmental agencies, institutions of higher education, and research centers, along with Ecuador's most renowned natural scientists, conservationists, and business leaders. The other half are conservationists, business leaders, and scientists from around the world. The Council meets twice yearly to conduct business, which includes the election of officers. One elected office is the Secretariat for the Americas, located at the Smithsonian Institution in Washington, DC.

The operational arm of the Charles Darwin Foundation is the Charles Darwin Research Station (CDRS). Established in 1961 as a permanent biological research station, the CDRS mandate is to preserve the Galápagos Islands as a living laboratory for future generations. Located on Isla Santa Cruz, the CDRS maintains a staff of approximately 50 people. About 20 of the staff members are scientific and educational employees who conduct applied conservation management research. They are supported financially by international institutions and by donations. The Park Service is funded by the government of Ecuador.

The Research Station and *Servicio Parque Nacional Galápagos* cooperate on projects that include:

- Raising endangered native species and reintroducing them to their former habitats.
- Controlling or removing introduced species, especially those that threaten the survival of native species.
- Establishing and maintaining nature trails with minimal disruption to plants, animals, and landscape.
- Guiding more than 60,000 visitors through the wildlife areas every year.
- Implementing conservation education programs, including Renacer, the Children's Conservation Club. (Its name is Spanish for "to be reborn.")
- Providing a base for university students doing research and for visiting scientific missions from all over the world. Several hundred such missions have used these services and facilities since the station was first established.

The physical facilities of CDRS include a fleet of dinghies for nearshore work and a vehicle for land transport. The station houses terrestrial labs; a small marine lab; staff offices; a library with a scientific reference collection; dorms; staff houses; lecture halls; a visitors center; electrical, mechanical, and carpentry shops; a dining hall; storerooms; nature trails; and facilities for raising endangered species.

The CDRS employs research and laboratory scientists, a variety of office workers, mechanics, and other support staff. Also in residence at the station is an old tortoise who is the only known remaining member of his species. Lonesome George has lived at the station since the early 1970s. Iguanas wander in and out of the laboratories on occasion, finches fly indoors to peck bits of sugar and bread crumbs from the dining room table, and marine iguanas scavenge in the trash cans, much as raccoons do in some US communities.

For current and updated information on the Galápagos Islands and the Research Station, read the journal *Noticias de Galápagos* (*News from the Galápagos*) published by the Charles Darwin Foundation. The text is primarily in English.

Issues in Preservation

Many of the challenges that affect the Galápagos also affect preserves, conservation areas, and parks elsewhere in the world. But since the Galápagos is a World Heritage area, it is especially important to make optimal use of its land and water, while considering the full range of human and environmental needs. These are some of the issues to think about:

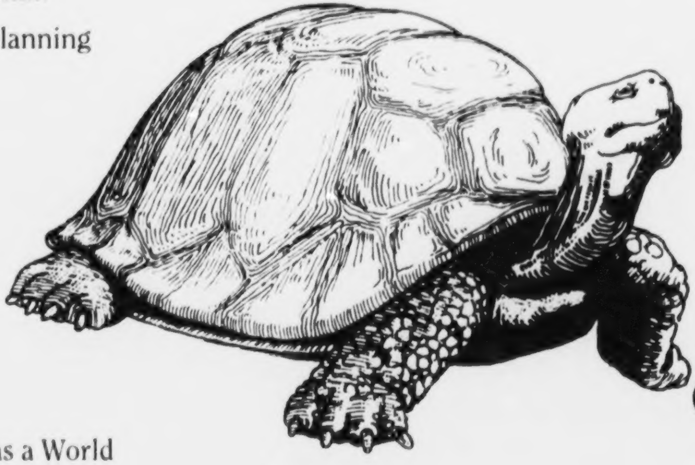
1. The needs of local human populations vs. preservation

In areas where humans live, socio-economic needs often conflict with habitat preservation. Some people might want to use the natural resources for food, to build homes, or to earn money. Others want the resources to remain as they are so many generations of people can study and enjoy them.

- How can these opposing viewpoints be reconciled?

- How can overuse and pollution destroy a habitat?

- Can local populations be involved in future planning for the areas where they live?



2. Use, but not misuse

Preservation is expensive. Resources must be purchased, protected, and maintained. The money to be made from tourism can help to offset these costs. If the area is developed, many people might make temporary financial gains. But too much development may cause the area to lose its appeal — not to mention its long-term value as a World Heritage.

- Who should set the limits on development?

- What kinds of restrictions should be placed on the visiting public?

- How much effort should be made to attract visitors by building hotels, gift shops, and other amenities?

3. Introduced species

The introduction of new species into the Galápagos has disrupted the natural order. Many iguanas in the Galápagos Islands, for example, are killed by dogs, an introduced species. Some of the original species have died out as a result of earlier human intervention.

- Why is it important to preserve the species native to the Galápagos?

- Should some foreign species be eliminated in order to return an area to its nearest pre-intervention state?

- Might it be possible to control introduced species without eliminating them?

- What criteria should be used to decide these issues?

A Research Station for the World

MASTER
1.2d

When you hear the word *laboratory*, you might think of a room with beakers and bottles and people in white coats doing experiments. There are other kinds of laboratories, though, and the Galápagos Islands is one of them. This *archipelago* (or cluster of islands, including the waters that surround them) is what is known as a "living laboratory." Research into the life cycles, habits, and habitats of its many life forms is going on daily. Every year, thousands of people study and enjoy the land and waters of the Galápagos.

What makes the Galápagos Islands so special? First, the islands are new, in geological time, and they are not connected to a continent, so we know that their life forms must have arrived either by air or by water. The islands are also far away from any place where there are lots of people, so they were not disturbed as often or as much as most other habitats. Today, people visiting the islands may feel as though they have stepped back millions of years in time, to the age of the reptiles.

Another reason the Galápagos are special is that people from many nations work together there. Though the Galápagos are part of the Republic of Ecuador, the Ecuadorian government has made the area a national park for international studies. Scientists and other concerned people from around the world cooperate to preserve the Galápagos ecosystem for the benefit of all species, including our own, both now and in future generations.

The Charles Darwin Research Station is on Santa Cruz Island. Here, scientists, teachers, and students conduct research on many areas of conservation. You will be reading about animals and plants found only on certain islands in the Galápagos Archipelago. People want to be sure the plants and animals will not become extinct. A species that may be close to extinction can be protected at the station and helped to breed.

The Research Station employs about 50 people year-round. Others come and go, conducting their research and then returning to the university or other institution that employs them. Scientists working at the station include geologists — especially volcanologists, since the islands are volcanic, and biologists — including herpetologists (who study reptiles), ornithologists (who study birds), botanists (who study plants), and ecologists (who study the interactions of the various life forms). There is work for naturalists, conservationists, park guides and guards, meteorologists, photographers, and biogeographers, as well as office workers, mechanics, electricians, cooks, carpenters, housekeepers, and gardeners.

MASTER 1.2e

The JASON Project Partners

Several major organizations are working together to make the JASON Project a successful venture. Some of the major contributors are listed here with a brief description of their contributions.

The JASON Foundation for Education is the overall coordinating organization of the JASON Project. The Foundation raises funds and promotes the project worldwide. Dr. Robert Ballard is the founder of the JASON Foundation for Education.

Woods Hole Oceanographic Institution (WHOI) has designed and built the JASON ROV system for deep-sea exploration. WHOI is contributing the personnel and equipment necessary to make the JASON expeditions.

EDS is providing the communications technology, management, and expertise to allow the live transmission of the expedition. EDS is assisting with satellite costs and is setting up command centers at the primary downlink sites.

National Geographic Society (NGS) is producing a film on the project and also providing magazine coverage. The TV film will be part of the *Explorer* series to be aired on Superstation TBS.

Turner Broadcasting System, Inc. (TBS) will produce 60 separate live shows during the broadcast period. They will be transmitted to the downlink sites via Atlanta, Georgia, by EDS.

Office of Naval Research (ONR) has provided government funds to help support the basic research that went into the production of the JASON ROV system.

National Science Teachers Association (NSTA) has worked with the National Council for the Social Studies to develop and produce this curriulum preparing teachers and students to come to the downlink sites for the JASON Project. NSTA is also assisting these sites with teacher training.

National Science Foundation (NSF) has provided funding to WHOI for research and development and to NSTA for the production of the curriculum.

Cray Research, Inc. is providing technical assistance to the satellite communications system and to the downlink sites' command centers.

Primary Interactive Network Sites (PINS) are the museums, universities, and other downlink sites in the United States and Canada that provide an auditorium command center and interactive equipment for students participating in the JASON Project.

JASON PROJECT

MASTER
1.2f

Checklist for the Expedition

Galápagos Flora and Fauna

Below are listed many of the plants and animals students will see when they view the expedition. Pictures depicting the flora and fauna are found on the poster and in Unit Three, Science.

Plants

- *Salt-resistant plant*
  - Mangrove
- *Dry-area plants*
  - Prickly-pear cactus
  - Candelabra cactus
  - Lava cactus
  - Galápagos tomato
- *Humid-area plants*
  - Scalesia
  - Miconia
  - Ferns
  - Mosses
  - Liverworts
  - Lichens

Animals

- *Reptiles*
  - Tortoise
  - Green sea turtle
  - Marine iguana
  - Land iguana
- *Birds*
- Galápagos penguin
- Red-footed booby
- Blue-footed booby
- Masked booby

- Flightless cormorant
- Waved albatross
- Tropic bird
- Brown pelican
- Swallow-tailed gull
- Galápagos hawk
- Frigate bird
- Flamingo
- Barn owl
- Vermilion flycatcher
- Ground finch
- Tree finch
- Cactus finch
- *Fish*
- Herbivorous (grazing) fish
  - Damselfish
  - Surgeonfish
  - Parrotfish
- Plankton-eating fish
  - Barber butterflyfish
  - Anchovy
  - Sardine
- Wrasse
- Grouper (*Bacalao*)
- Tuna
- Squid
- White-tipped shark
- Galápagos shark
- *Mammals*
- Humpback whale
- Killer whale
- Bottle-nosed porpoise
- Fur seal
- Sea lion
- Red bat
- Rice rat

Introduced species

- Goat
- Dog
- Pig
- Burro
- Horse
- Cow
- Cat
- Sheep

Miscellaneous

- Seaweeds (marine algae)
  - Ulva, or sea lettuce
  - Ceramium
  - Sargassum
- Plankton—both phytoplankton and zooplankton
- Gastropods
  - Littorina
  - Nerita
- Sea urchin
- Barnacle
- Sally Lightfoot crab
- Sea anemone
- Coral polyp
- Octopus

WHY THE GALÁPAGOS?

1.3

ACTIVITY ONE

Aluminontos: A Taxonomy of Pull Tabs

Rationale This year's JASON expedition will visit the Galápagos because its unique ecosystem offers many opportunities for students to observe along with scientists, and to learn how they conduct their work. Scientists need to make detailed, correct observations in order to interpret what they see. Small outward differences among individual objects of study often indicate other important differences that are less apparent.

VOCABULARY

Dor•sal - belonging to the top side.

Ven•tral - belonging to the under side.

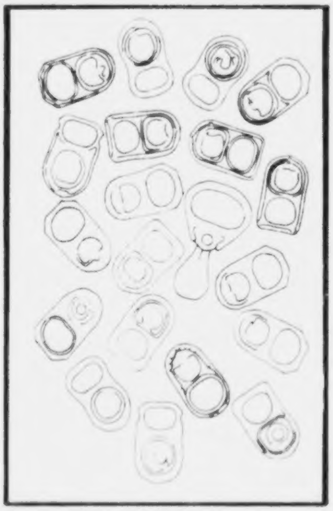
Tax•on•o•my - the branch of study that deals with the classification of organisms.

Objectives Students will:

Read about the scientific observations of Charles Darwin.

Demonstrate an ability to observe small differences among common items.

Classify items on the basis of small differences.



Materials

- Student copies of Master 1.3a, Charles Darwin
- Drawing paper and pencils
- 20 aluminum pull tabs per team
- One or more pull tabs of the older type that lifts off to open rather than staying attached to the can *(optional)*
- Student copies of Master 1.3b, Aluminontos (*optional*, for younger students adaptation)
- Back of Master 1.3b, Answer Key (*optional*)
- Scissors, unlined paper, tape or glue (*optional*)

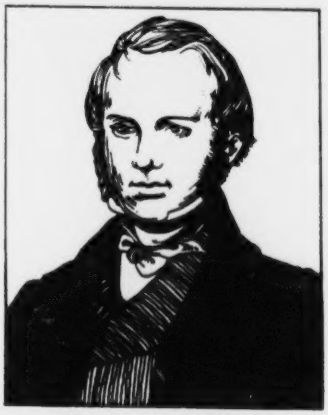
Procedure

Teacher Preparation

Gather enough pull tabs for your class, or assign the students to gather them. If your time is limited, or your students are very young, make copies of Master 1.3b instead.

A. Introduction

Distribute copies of Master 1.3a. Read it with the class or give students time to read silently. Briefly discuss Charles Darwin's contributions to science. Explain that when Darwin first visited the Galápagos and made his collection of plant and animal specimens, he didn't notice the differences among organisms on different islands; for example, that different islands in the archipelago held different species of finches. Only after reading Vice-Governor Lawson's observation that each island had its own particular life forms did he go back to his specimens and note their differences.



Charles Darwin

B. Lesson Development

1. Distribute drawing materials and challenge students to test their own powers of observation by drawing a familiar object—an aluminum pull tab from a soft drink can—without looking at it.

2. Divide the class into pairs or groups of three and have students compare their drawings. Have they all noted the same characteristics of pull tabs? Do all the drawings look alike, or did individuals have different types of tabs in mind as they produced their drawings?

3. Give each team of students about 20 pull tabs from beverage cans of different brands. Have them study the characteristics of the pull tabs as if they were organisms ("aluminontos"). Identify the dorsal and ventral sides. Which end is the head? How do the student drawings compare to the actual objects?

4. Direct the students to sort the aluminontos into groups on the basis of similar characteristics. They will need to discuss how the aluminontos differ from each other and which differences are great enough to be used as criteria for classification. (The back of Master 1.3b shows one sample grouping, but many others are possible.)

5. Lead a class discussion of the processes groups used to make their classifying decisions. Some groups may only have looked at large, obvious features, as Darwin did initially. Others may have noticed fine details by which to classify. Emphasize that practice in observing will lead to better scientific results.

TEACHER TAKE NOTE

Take this opportunity to discuss recycling of aluminum and the potential problems these pull tabs can cause if improperly discarded.

Adaptations

For younger students

You may choose to use the master and its accompanying materials instead of the actual pull tabs. Or use the master first to prepare students for collecting and classifying the real "aluminontos."

For older students

Enlist the students' help in gathering the specimens for study. Senior high students should be able to construct hypotheses related to the evolution of aluminontos and the value of various adaptations for the "organisms."

For all students

Show the class a pull tab of a type that is now nearly extinct: those that pull off part of the can lid in order to open it. (This tab is in a classification by itself on Master 1.3b.) Discuss why the species is rare in today's environment.

Expedition Review

Remind students that Darwin had to sharpen his observing and recording skills before he could use the information he gathered in the Galápagos to best advantage. They also must use their best observing skills in order to get accurate journal entries at the downlink site.

The idea for this activity was derived from S. J. Hageman, [March 1989], "Use of Aluminontos to Introduce General Paleontologic and Biostratigraphic Principles," *Journal of Geological Education* 37 [2]: 110-113.

ACTIVITY TWO

Management for Conservation

Rationale

Environmental challenges are a part of today's reality. The Galápagos ecosystem is unique, but the same principles apply to its management as to the management of problems close to home. As we learn about the creatures of the Galápagos Islands and their interactions with their environment, we learn how to maintain the integrity and diversity of ecosystems elsewhere in the world.

Objectives

Students will:

Identify local environmental problems and their sources.

Determine possible solutions.

Examine the relationship between a local environmental problem and the problems facing the Galápagos.

VOCABULARY

Con•ser•va•tion - a wise and responsible use of resources.

Herb•i•vore - an organism that eats plants.

In•ter•de•pen•dence - a relationship in which organisms meet each other's needs.

In•tro•duced spe•cies - organisms not native to a region, but brought in from outside and allowed to propagate.

Materials

- Newspapers and periodicals (some current, some older)
- Writing materials (*optional*)

Procedure

A. Introduction

Briefly review the second lesson in this unit. Explain that because they are isolated 1,000 kilometers from the nearest mainland and hold species that exist nowhere else on Earth, the Galápagos Islands are a natural laboratory in which to study conservation. The interdependence among the native species is a delicate balance, and easily upset. When the population of any plant or animal species shrinks or expands, all the other species in the ecosystem are affected.

The Galápagos National Park Service works with the scientists at the Research Station to maintain this natural balance, and restore it, insofar as possible, where it has been lost. Introduced species pose the greatest threat. When visitors brought goats to the islands of Española and Santiago, for example, probably to raise for their meat and

TEACHER TAKE NOTE

Depending on the age of your students, the availability of material on the problem they select, and the resources available in local libraries, you may distribute periodicals that you have collected or assign students to do research on their own.

milk, the animals had no place in the ecosystem. They threatened tortoises and land iguanas by competing for their food. Since there were no predators on the islands adapted to preying on the goats, they were able to multiply unchecked, with devastating and widespread effects. The goats have now been removed from these two islands.

TEACHER TAKE NOTE

Lesson 8 in Unit 3 and Activity Two, in Lesson 3, Unit 4 both deal with the problem of introduced species in more detail. You may want to read them now for background, or plan to teach one or both at a later time.

B. Lesson Development

1. Elicit from the class what they already know about environmental problems. Discuss the importance of recognizing and solving them. Identify one or more problems that affect your community. (Solid waste disposal is a problem in most parts of the country, but there may be more pressing issues close to home.)

2. Distribute magazines and newspapers with articles about the problem(s), or assign students to locate their own as a homework assignment.

3. When students have located articles and read them, ask several volunteers to share what they have learned with the class.

4. Build a class discussion around these questions. If the class researched more than one problem, go through all the questions for each one.

- What is the problem?

- What is the source of the problem?

- How widespread is the problem?

- What is being done to solve the problem?

- Are private agencies (such as businesses) or governmental agencies taking the lead? If both are involved, are they working together or in opposition? (Explain to students that the goat problem in the Galápagos was solved by collaboration among the Galápagos National Park Service, the Ecuadorian government, and the Charles Darwin Foundation, a non-governmental, international scientific organization.)

- Is there anything we can do as individuals to help solve this problem or lessen its impact?

C. Conclusion

Ask:

- What elements do all the problems, both at home and in the Galápagos, have in common? (Possible answers might include: They all took time to develop, and will probably take some time to solve; they all began with people not meaning to do harm, but failing to take a long-range view.)

- What elements do good solutions have in common? (Emphasize the role of cooperation among all the parties affected.)

Adaptations

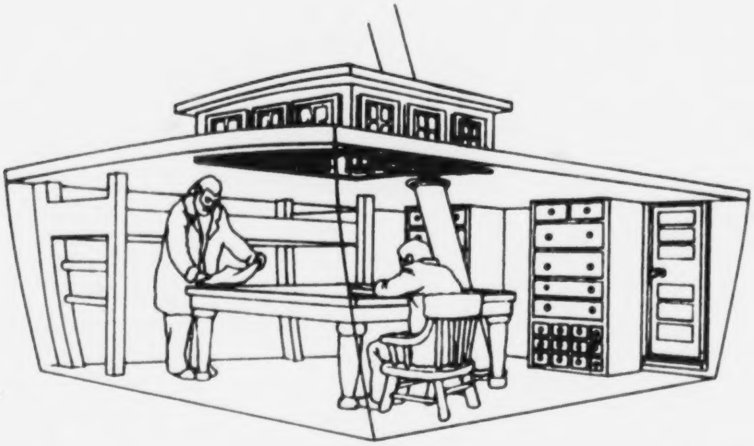
For all levels

1. Challenge students, either orally or in writing, to propose their own solutions to the problems they have discussed. What should be done that is not currently being done?

2. Assign students to write a letter to a representative of one of the groups involved in solving a local environmental problem, offering their best advice. If the class discussion has identified things students can do to help, be sure to include those—especially if students are doing them.

Expedition Review

Relate conservation in the Galápagos to local, national, and world events. Remind students to be aware of conservation efforts in the Galápagos throughout the program.

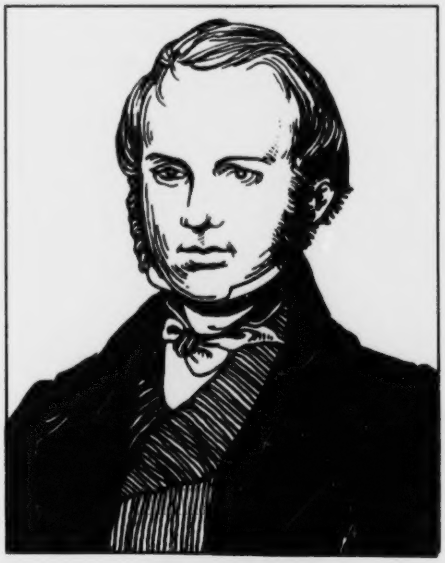


Charles Darwin aboard the *Beagle*

43

Charles Robert Darwin (1809-1882)

Biographical Sketch


Charles Darwin as a young man

You might think it strange that a man famous for his scientific work did not like science class when he was a boy. But when Charles Darwin was in school, science class was often only a lecture. Charles could listen, and he liked to read, but the science he liked best was the kind he could get his hands on. He loved to ramble for hours collecting insects, plants, and minerals.

Charles Robert Darwin grew up in the English town of Shrewsbury early in the 19th century. His father was a successful doctor, and he expected Charles and his brother Erasmus to become doctors, too. Neither of them did, though they and their friends were fascinated with the sciences. The brothers loved to set up chemistry experiments in their home laboratory. The experiments were so often smelly that Charles' fellow students nicknamed him "Gas"–and he was still "Gas" to his brother when they were both distinguished gentlemen.

Before Charles was 20, he had earned a reputation among scientists for his careful identification of beetles, including some previously unknown species. He went to Edinburgh, in Scotland, to study medicine, but he enjoyed the small academic societies where undergraduates met to read their papers much more than he enjoyed the classes. After two years, Dr. Darwin shipped his youngest son off to Cambridge to become a clergyman instead. Charles wasn't unhappy with the idea, since country pastors seemed to have lots of free time to pursue their own interests, and he accepted the teachings of the Church. But at Cambridge, too, he learned more from his friends and his own explorations than from his classes. He continued his hobby of collecting, and he made friends with members of the science faculty. Most important were J.S. Henslow, Professor of Botany, and Adam Sedgwick, Professor of Geology. Henslow took Darwin under his wing, and the young theology student attended lectures and participated in botany field trips. He also took nearly daily walks with the scientist, which were extremely important in developing Darwin's habits of observation.

When Darwin graduated, Henslow arranged for him to join Professor Sedgwick on a geological expedition to North Wales. It was also Henslow who arranged for Charles to travel as unpaid naturalist and companion to Captain Robert FitzRoy on the voyage of the *Beagle*. Darwin set sail from England on 27 December 1831.

He was observant, well read, and well prepared for such an opportunity. He turned 23 soon after sailing on the *Beagle*; he would be almost 28 when he returned home to England. During those five years Darwin studied the animals, plants, land forms, and fossils of many countries and islands. He dissected animals and plants, kept a journal, and wrote letters to friends and colleagues describing his observations and enclosing preserved specimens and fossil bones. Because of his energetic and careful studies, Darwin was already a famous naturalist by the end of the expedition. He said later that a major benefit from his *Beagle* experience was his improved power of concentration on whatever he was doing. He called it the first real training of his mind.

Darwin's first tasks after returning from the voyage were to go over his journal and to organize his collections. By the time he had finished, at the age of 29, he had developed his theory on the evolution of species. But Darwin did not want to publish his theory until he had gathered all the supporting information he could find. Whenever possible he developed experiments to test his ideas. Beginning in July, 1837, he kept a series of notebooks recording his observations of specimens, reflections on what he had seen in his travels, and the results of his many experiments. Darwin spent 20 years on this task, and in 1859 he finally published his master work, *On the Origin of Species by Natural Selection*.

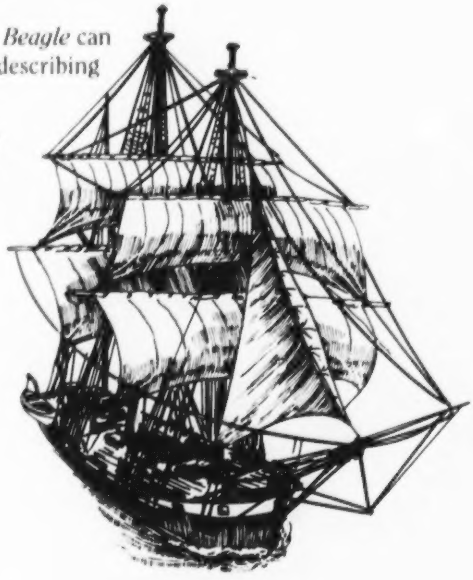
When this work was first published the edition sold out immediately, but Darwin was attacked in the newspapers and scientific journals. Part of the problem was that in 1859 scientists did not know how genetic variations are passed from parent to offspring. The Austrian monk Gregor Mendel had already done experiments with garden peas that would have helped Darwin explain his theory, but Mendel's work was not discovered by scientists until 1900. Darwin's observations and experiments were so thoroughly documented by the time he published, however, that some other naturalists did agree with his conclusions. Some had even come to similar conclusions on their own.

As the controversy over his book raged on, Darwin continued to work, publishing ten more books before his death in 1883. He led a quiet, routine life with his wife and children at their home in the country. His health had not been good since he returned from the Galápagos. He suffered from sleeplessness and chronic pain. Nevertheless, he accomplished an enormous amount of work, and answered all his mail courteously, even when the writers blasted his theory and called him names.

Darwin's letters, his autobiography, and the journal of his trip on the *Beagle* can be found in most libraries. Below is a small sample from his journal, describing his first look at the waters surrounding the Galápagos Islands:

> *The bay swarmed with animals; Fish, Shark, & Turtles were popping their heads up in all parts. Fishing lines were soon put overboard & great numbers of fine fish 2 & even 3 feet long were caught. This sport makes all hands very merry; loud laughter & the heavy slapping of the fish are heard on every side.*

As you continue your own journal, in the next lesson, and when you join the expedition by telepresence, remember to be a careful observer of all that is around you to see, hear, feel, and touch.



H.M.S. Beagle

Sources:

Barlow, Nora, ed. (1969). *Charles Darwin's Diary of the Voyage of the H.M.S.* Beagle. Cambridge at the University Press, New York: Draus Reprint Co.

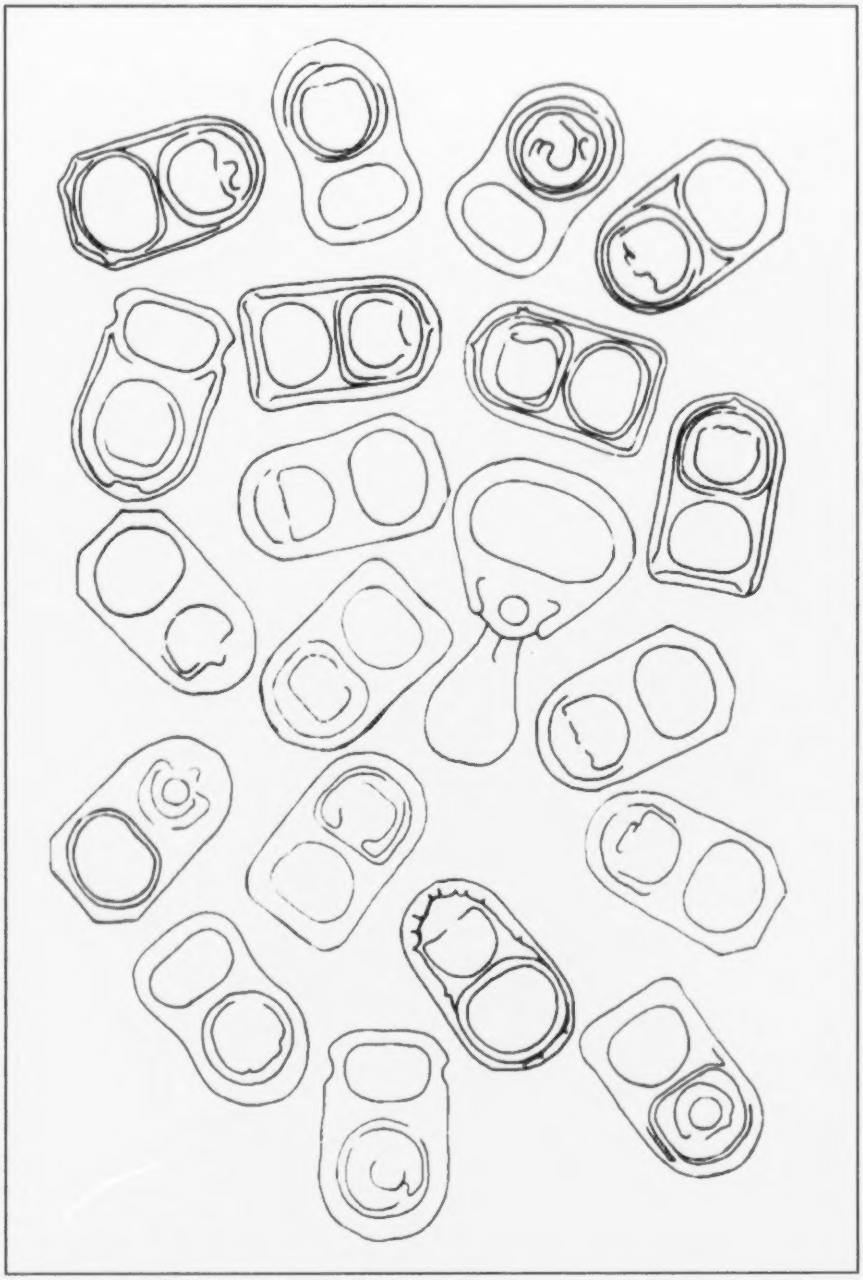
Darwin, Francis, ed. (1986). *The Life and Letters of Charles Darwin Including an Autobiographical Note. Vol. 1D. New York: Appleton and Company.*

Olby, Robert. (1967). *Charles Darwin*. The Clarendon Biographies. Oxford: Oxford University Press.

Aluminontos

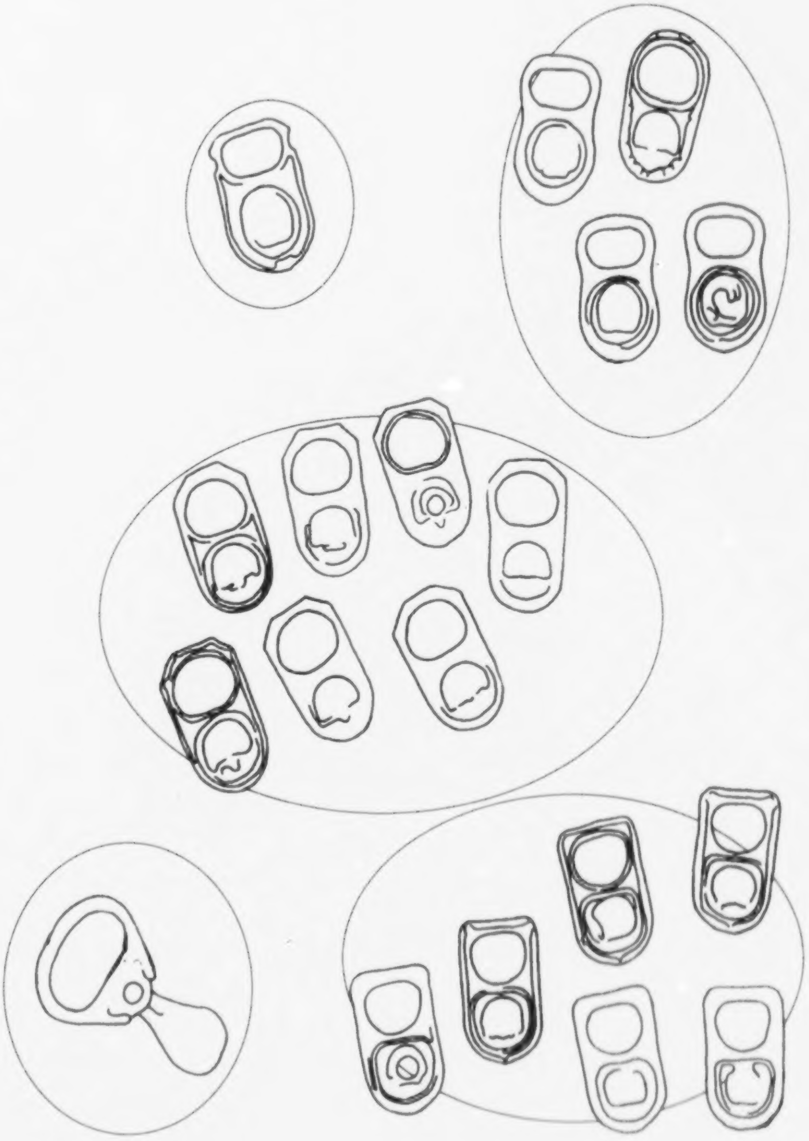
Directions

1. *Observe these 20 specimens closely, noting the distinctive features of each.*
2. *Cut them apart.*
3. *On the basis of your observation, rearrange them on a clean sheet of paper into groups, or species. Tape or glue the aluminontos in place.*
4. *Be prepared to explain the reasons for your classification.*



Aluminontos Answer Key

Here is one possible grouping. There are others.



THE GALÁPAGOS

JASON CURRICULUM

UNIT TWO

TECHNOLOGY

BACKGROUND
Technology

Technology is the underlying theme of the JASON Project. Without it, Robert Ballard would not have been able to find and investigate the *Titanic*, discover geothermal vents in the Mediterranean, or explore the bottom of Lake Ontario, and scientists, engineers, educators, and thousands of students would not have been able to go along with him.

Technological developments have opened new frontiers of knowledge. The tools that evolved from technology allow modern-day explorers to observe areas once considered impenetrable because of the hostile nature of the physical environments. Extreme temperature, darkness, and pressure all contribute to make the lake and ocean floors virtually unexplored areas of our planet. The JASON/Jason Jr. system of remotely operated vehicles (ROVs) makes this new frontier accessible to us. The ROVs are robots whose imaging systems and maneuvering capability use state-of-the-art technology, uniquely configured and expressly developed to involve students and educators directly with the excitement of scientific discovery in the field.

The real-time transfer of live images from this expedition is a nearly unprecedented phenomenon. The communications scientists and project engineers have combined their skills and problem-solving abilities to bring the JASON adventure to thousands of people who have never before embarked on an exploration.

Exploration takes a lot of time and money. When Dr. Ballard discovered the *Titanic*, two and a half hours of observation time in a submersible vehicle required a five-hour trip to the bottom of the ocean and back again. With the use of a remotely operated vehicle, such as Jason Jr., real-time observation is limited only by the stamina of the observers on the command ship. Increasing the observation time so dramatically makes underwater exploration more efficient and cost-effective than ever before. Remote observation also allows a greater number of scientists, historians, and students to take part. With more minds engaged, more analysis and interpretation can take place, increasing the value of the exploration.

The Galápagos JASON Project adds yet another interactive dimension to enhance the involvement of students. This year, like last year, selected students will have the opportunity to ask Dr. Ballard questions through a two-way audio hook-up and to actually drive Jason Jr., using a joystick at their local downlink site's simulated command center. In addition, this year some students will be able to answer questions posed by Dr. Ballard during the downlink, using keypads located at many of the downlink sites. By putting students at the forefront of the mission and involving them in team interactions, these innovations are making Robert Ballard's vision of telepresence a reality.

The Technology Unit of the NSTA Galápagos JASON Curriculum is critical to the understanding of the overall project. Therefore, it is essential that you review this unit carefully and select one or more activities from each of the lessons to use with your students. When they have completed this unit, your students should have the necessary background in robotics, satellite communications, and image transmission to understand how they will be "telepresent" on and around the Galápagos Islands with the JASON team.

DIVING TECHNOLOGY

2.1

ACTIVITY ONE

The Ups and Downs of Diving

Rationale

Whether an object will sink, float, or remain at a constant depth depends on the interaction of two opposing forces, weight and buoyancy. Since all underwater objects, including both Jason Jr. and the scuba diver, are subjected to these forces, it is important to understand their effects on submerged objects.

Objective

Students will:

Observe the formation of gas bubbles on raisins.

Explain in their own words how things can be made more buoyant.

Materials

- Raisins
- Club soda
- Clear plastic cup or glass for each group of students

VOCABULARY

Buoy•an•cy - a force that acts upon an object causing it to float.

Neu•tral buoy•an•cy - a condition in which the forces of weight and buoyancy offset each other, so that an object will neither sink nor float, but remain at a constant depth.

Scu•ba (**S**elf-**c**ontained **u**nder-water **b**reathing **a**pparatus) - a diving technology pioneered by Jacques Cousteau and Émile Gagnan. Scuba divers breathe underwater from a tank of compressed air.

Weight - a force resulting from the gravitational attraction of the Earth's mass which causes an object to sink.

Procedure

Teacher Preparation

Try this activity out before class to make sure that at least some of the raisins will float. If the raisins you have do not float, experiment with other varieties until you find one that works.

A. Introduction

Ask the class: Why do some objects float? Explain that whether an object will sink, float, or remain at a constant depth depends on the interaction of two opposing forces. One force is called weight. Weight is produced by the gravitational attraction of the Earth's mass acting on the mass of an object. The greater the mass of an object, the greater its weight. The other force is called buoyancy. This force is produced by displaced matter. It pushes objects upward. The greater the volume of water displaced by an object, the greater the buoyant force which acts upon it.

An object will float when the buoyant force is greater than its weight. An object will sink when its weight is greater than the buoyant force. When the buoyant force and weight are equal, the object will be *neutrally buoyant*.

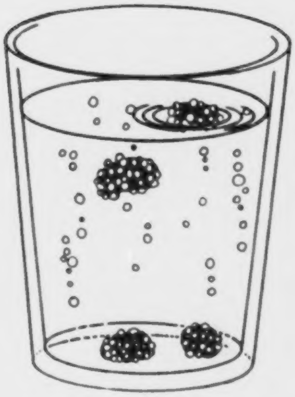
B. Lesson Development

1. Divide the class into cooperative learning groups or teams.

2. Supply each group with several raisins and a plastic cup two-thirds full of club soda.

3. Instruct the students to drop the raisins into the cup and observe what happens.

4. Have each group suggest a hypothesis to explain their observations. List the hypotheses on the board. As a class, compare and evaluate these "educated guesses."



C. Conclusion

Help students draw conclusions which relate the rising and sinking behavior of the raisins to the buoyant effect. Make sure students understand that even gas bubbles have weight, but the buoyant force acting upon the bubbies is much greater than the weight of the gas they enclose. Ask the following questions:

- What happened when the raisins were first placed in water? (They sank.)

- Which of the two forces acting upon the raisins was greater? (weight, or the force of gravity)

- What appeared on the surfaces of the raisins? (gas bubbles)

- What happened to the raisins which were covered with gas bubbles? (They rose to the surface.)

- Why did the raisins rise? (The buoyant force produced by the air bubbles attached to the raisins was greater than the weight of the raisins, and so they rose.)

Adaptations

For older students

1. Invite students to vary this activity by using different objects, such as small charms, beans, peas, or dry-roasted peanuts. Explain that the bubbles contain carbon dioxide that has dissolved out of the soda water solution.

2. Have students compare the rate at which bubbles appear in "flat" soda water and soda water which still has its fizz. Try adding salt to the water to increase its density, making it more like ocean water.

Expedition Review

Students should review:

a) the balance of forces which result in sinking, floating, and neutral buoyancy.

b) the effect of air bubbles on submerged objects.

ACTIVITY TWO

Neutral Buoyancy

Rationale

Jason Jr. (JJ) was constructed to be *neutrally buoyant* with respect to its watery environment. Because it is neutrally buoyant, this ROV does not have to expend energy to remain at a constant depth. Scuba divers also try to conserve energy by adjusting their gear to attain neutral buoyancy.

VOCABULARY

Den•si•ty - the amount of mass an object has per unit of volume.

Objectives

Students will:

Predict and observe the behavior of regular and diet soft drink cans when immersed in water.

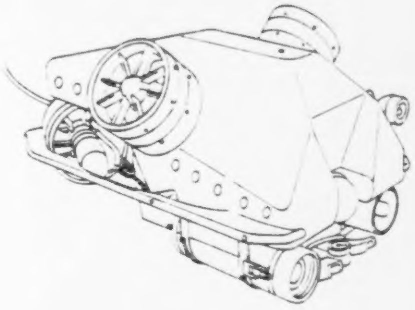
Calculate the density of solutions using mass-volume data.

Design and construct a neutrally buoyant vessel.

Relate density to neutral buoyancy.

Materials

- Balance
- Aquarium or other large, deep, straight sided container filled with water
- One sealed can each of regular and diet soda (same brand) at room temperature
- One empty can of each type of soda
- Paper towels
- Pencils and paper for student data tables
- Ice (*optional*)
- Plastic foam (cups, blocks, strips, or poly puff "packing worms")
- Finishing nails or metal washers, several sizes
- Tape, preferably water resistant
- Scissors



Procedure

A. Introduction

Review the concepts of buoyant force and weight as presented in the first activity. Ask students for examples of objects or substances which will

- sink in water.

- float in water.

- hover (neither sink nor float) in water.

Explain that if an object has a density similar to that of the surrounding water, displacing the same mass of water as its own mass, it will neither sink nor float, but will hover. Discuss the importance neutral buoyancy to both Jason Jr. and scuba divers.

TEACHER TAKE NOTE

Unless your students are familiar with the concept of buoyancy, do Activity One as preparation for this activity.

B. Lesson Development

1. Perform this demonstration:
a. Show the students unopened cans of regular and diet soda. Ask how they can tell the difference between the two cans. Write or summarize their responses on the board.
b. Ask the class to predict what would happen if the cans were placed in water.
c. Place the can of regular soda in water (it should sink), then the can of diet soda (it should float). Compare observations with predictions.

TEACHER TAKE NOTE

These are some good brand pairs to use: Coke Classic™ vs. Diet Coke™, 7-Up™ vs. Diet 7-Up™. Some other brands may not exhibit significant differences between regular and diet versions. If the expected result does not occur at room temperature, try ice cold cans in ice water.

2. Ask students to offer probable explanations for their observations. Refer them to the list of ingredients on the side of each can. Do the different solutions contain anything which might make them more or less dense? Discuss.

3. Distribute plastic foam and nails or washers. Give these directions for a student experiment:
a. Set up a data table for recording mass, volume, and density.
b. Determine the mass of an empty, dry, regular drink can and a diet drink can. Determine the mass of a full, unopened can of each solution and record. Read the volume of solution from the side of each can. Record this information in your data table.
c. Determine the overall volume of your unopened cans by water displacement. How do these volumes compare with the volume of the contents indicated on the side of the cans?
d. Calculate the density of the unopened cans by dividing the mass by the volume of each can.
e. Modify your cans to make them hover in the middle of the container of water. Use plastic foam materials and metal nails or washers to raise or lower the cans.

4. Use these questions as the basis for a class discussion:
- How do the densities of the regular and diet drink solutions compare to the density of water, which we will assume to be 1 g/mL? (Actually, at room temperature, the density of water is slightly less than this. The regular drink should have a density greater than that of water, while the diet drink's density should be less.)
- Do the densities explain what you observed when the drink cans were placed in water? (Yes)
– How does the density of some thing which will sink compared to that of the fluid surrounding it? What about the density of something which floats? Something that hovers? (Objects float because they are less dense than the fluid in which they are immersed; objects sink because they are more dense than the fluid in which they are immersed. An object such as JJ that has a density equal to its surrounding fluid will hover at whatever depth it may be.)
– Explain why modifications to the originally sinking and floating cans caused them to hover. Why would an object that hovers be easier to maneuver than one that sinks or floats? (JJ is highly maneuverable since the operator can move it in any direction without spending time getting it up from the bottom or down from the surface. Extra equipment to control sinking and floating is not necessary.)

C. Conclusion

Sum up the discussion by explaining the difference between the two types of sodas. Regular soft drinks are sweetened with dissolved sugar and/or high fructose corn syrup. A great quantity of this relatively heavy substance is required to sweeten regular soft drinks. The artificial sweeteners in so-called diet drinks are many times sweeter than sugar, and so they are required in smaller quantities. Therefore, regular soft drinks are more dense than water, and diet drinks are less dense.

A scuba diver can regulate his or her overall density in two ways. By filling a special diving vest with air, the diver can make him/herself lighter and more buoyant. By releasing air from this vest, the diver can become heavier and less buoyant. A diver can also alter his or her density by adding lead weights to a weight belt or taking them out. Students may see Dr. Wellington, the JASON diver, use weights for this purpose during the JASON Project transmission.

Adaptations

For younger students

You may want to limit the lesson to a demonstration and discussion of the drinks in water. Do not include the concept of density with its calculations and graphs if the students are not ready to grasp this mathematical concept.

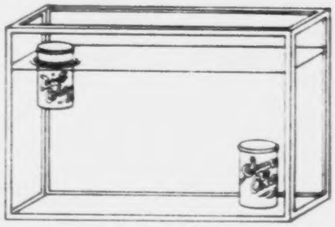
The Elementary Science Study (EES) unit *Colored Solutions* contains many simple activities with salt solutions of different densities.

Expedition Review

Students should review:

–why it is desirable for divers and submersibles to be neutrally buoyant.

–how buoyancy can be affected by changes in an object's overall density.



ACTIVITY THREE
The Cartesian Diver

Rationale

Scuba divers use the buoyant effect of air to help them adjust or maintain their level of depth. This simple and inexpensive activity illustrates how varying a volume of air affects its buoyant force.

Objective

Students will:

Construct a Cartesian diver.

Observe the relationship between pressure and volume.

Change an object's overall buoyancy.

VOCABULARY

Vol•ume - a measure of three-dimensional space (cubic meters, cubic feet).

Pres•sure - force applied to a given surface area (grams per square centimeter).

TEACHER TAKE NOTE

If sinks are not accessible, the 2-liter containers can be filled almost to the top prior to class time. During this activity, use a pitcher to "top off" the containers.

Materials

- 2-liter clear plastic beverage bottle with cap for each group
- Water to fill the containers
- Medicine dropper or eye dropper for each group

Procedure

A. Introduction

Review the relationship between buoyant force and weight as presented in the first activity.

B. Lesson Development

1. Divide the class into cooperative learning groups or teams.

2. Supply each group with a 2-liter plastic container and a medicine dropper.

3. Instruct the groups to follow these steps:

- Fill their 2-liter containers to within a centimeter of the top.

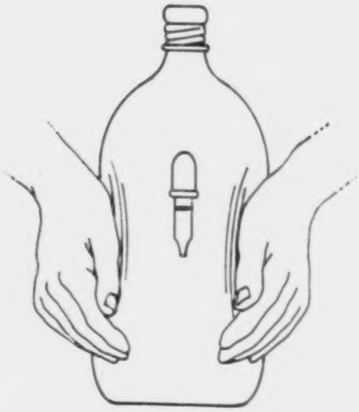
- Fill the medicine dropper about two-thirds full of water and place in the container.

- Slowly add more water to the container. Stop when the container can hold no more.

- Screw the cap on tightly. Observe the behavior of the dropper. (It floats.)

- Squeeze the plastic container and observe what happens to both the dropper and the volume of air within its glass tube.

4. Have each group suggest a hypothesis for its observations. As a class, compare and evaluate these hypotheses.



C. Conclusion

Again referring to the first activity in this series, explain that as the volume of an air bubble decreases, so does its buoyant force. Squeezing the bottle increases the pressure within the bottle. The increased pressure causes more water to enter the dropper and the air bubble inside the dropper compresses and gets smaller; its volume decreases. The dropper with this additional water is now heavy enough to sink.

Adaptation

For older students

Review Boyle's Law, and investigate how this relationship between pressure and volume is applicable to the Cartesian diver. Then, by determining the volume change of the diver's air bubble, have students find the pressure increase applied to the system.

Expedition Review

Students should review:

– the relationship between air volume and buoyancy.

– the relationships among depth, pressure, and volume.

ROBOTICS

2.2

ACTIVITY ONE

What Can a Robot Do? What Can't It Do?

Rationale The robot Jason Jr. (JJ) is a key component in this year's JASON Project. To understand JJ's functions, students need to know what robots can and cannot do.

VOCABULARY

Pro•gram - a set of instructions.

Ro•bot - a programmable machine with moving parts that can manipulate objects to do some kind of work.

Objectives Students will:

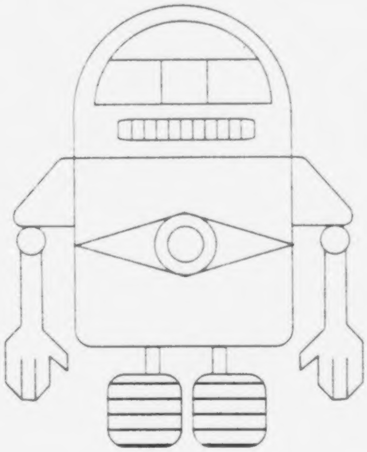
Discuss the advantages and disadvantages of robots.

Compare characteristics of robots and humans.

Write a program for a robot to successfully express perform a simple task.

Materials

- Transparency made from Master 2.2a, Kinds of Robots
- Paper
- Pencils or pens
- Student copies of Master 2.2b, Robotics Worksheet
- Student copies of Master 2.2c, Robot Specifications, one for each small group
- Teacher Background Information on reverse of Master 2.2a
- One table setting: plate, cup, fork, knife, spoon (Plastic or paper is fine.)
- Placemat and napkin
- Large file card labeled ERROR, one for each "robot"



Procedure

A. Introduction

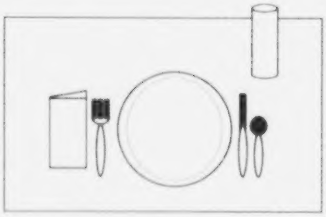
Ask: Do all robots look alike? Are the biggest robots necessarily the the best? Project Master 2.2a, Kinds of Robots, and explain the functions of the robots pictured. Emphasize that most robots are not humanoid like the ones in movies and on TV. Explain that robots are often designed and selected for specific jobs. The next two activities will help the students understand how robots work and why they are chosen for particular jobs.

Distribute copies of Master 2.2b, Robotics Worksheet, and give students time to do the exercise. Then divide the class into pairs or small groups and let students compare and discuss their answers. Follow with a brief class discussion about the advantages and disadvantages of robots.

B. Lesson Development

1. Divide the class into teams of four students, and give each team a copy of Master 2.2c, Robot Specifications. Have each team designate a student "robot." The rest of the team will serve as programmers. Give students three minutes to select the robot and designate roles for the other three students.

2. Set a place setting, such as the one illustrated, on a table in front of the classroom. Ask each group to write a step-by-step program instructing its robot to remove the items from the place setting one-by-one and reproduce the identical place setting on a nearby table or desk. Give students about 12 minutes to write their programs and practice the place-setting task. (Students who are unfamiliar with programming may require more time.)



3. Caution students to use only the commands listed on Master 2.2c, Robot Specifications, in writing their programs. All commands must be short and specific.

4. When all the teams have finished their writing, call the teams to take turns reading their programs, one step at a time, to the designated robot. Robots should respond to the commands according to the Instructions for Robots on Master 2.2b. If the programmers use any term that is not on the list, the robot must pretend not to recognize it, and hold up the ERROR card.

C. Conclusion

Discuss how well each team's robot performed the place-setting task. Which robot instruction programs resulted in the most error messages? The least? If time permits, have students repeat the activity, trying to reduce the number of error messages and accomplish the task in less time.

TEACHER TAKE NOTE

You may want to introduce the students to programming by writing and demonstrating a short program. Be sure to include an error, such as omitting the stop command.

Adaptation

For older students

Challenge students to write a program that would enable a "robot" classmate to perform a more complex task, like tying a shoelace or a necktie, using the specifications on Master 2.2c.

ACTIVITY TWO
Make It Snappy!

Rationale

The ROV JJ has been chosen for this year's JASON project because it can accelerate more quickly and maneuver more easily than the much larger JASON. This activity will demonstrate the relationship between JJ's maneuverability and its mass.

Objectives

Students will:

Define acceleration, inertia, and maneuverability.

Judge which of two objects is more maneuverable.

Explain why one object accelerates faster than the other.

VOCABULARY

Ac•cel•er•a•tion - rate at which an object speeds up or slows down.

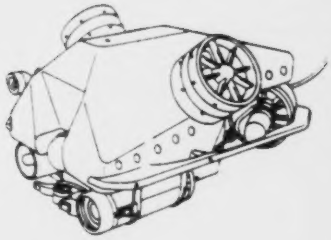
In•er•tia - the property of matter that causes it to remain at rest or in uniform motion in a straight line unless acted upon by an outside force (Newton's first law of motion).

Ma•neu•ver•a•bil•i•ty - ease with which an object can change positions.

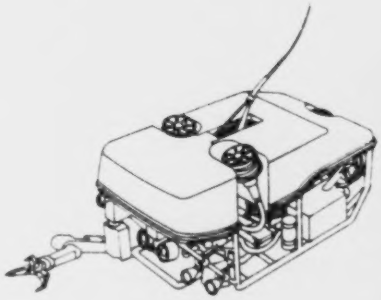
So•nar (**So**und **n**avigation **a**nd **r**anging) - both the method and the instruments that employ the re flec tion of sound waves to locate objects, define surface features, and determine water depth.

Materials

- Transparency made from Master 1.1e, Three Submersibles
- Overhead projector
- For each group, two cylindrical bottles, one several times larger or heavier than the other, such as 330-mL and 1000-mL plastic containers for bottled water
- For each group, 8-10 rubber bands strong enough to lift the larger bottle when full of water
- Meter stick for each group
- Student copies of Master 1.1e, Three Submersibles (*optional*, for lower-grades adaptation)
- Felt markers of two widths (*optional*, for lower-grades adaptation)
- Pencils and paper for recording observations
- A large trough or washtub filled with water (*optional*, for upper-grades adaptation)
- An assortment of 1-lb food packages of different sizes and shapes—bags, boxes, cans and other rigid containers (*optional*, for upper-grades adaptation)



Jason Jr.



JASON

Procedure

A. Introduction

Tell students that JJ, not JASON, will be exploring the deep-water site on this expedition. Remind students of the decisions they made Lesson One of Unit 1, selecting the most appropriate ROV for each of several underwater missions. Give examples of some ordinary tasks and the tools best suited to them. Ask: Would you take a microwave oven on a picnic? Why or why not?

B. Lesson Development

TEACHER TAKE NOTE

Be sure you have done Activity Two in Lesson One, Unit 1 as a preparation for this activity.

1. Project the transparency made from Master 1.1e, Three Submersibles. Tell students that JJ was developed to help Dr. Ballard explore the *Titanic*. Ask: Why is a robot (ROV) better suited for undersea exploration than a human being? (Students may mention size, pressure threshold, data collection capacity, and low human risk factor.)

2. Write the vocabulary words on the chalkboard and go over their definitions. Discuss any concepts that are not clear to the students.

3. Ask students to point out some obvious differences between JJ and JASON. Have them estimate the size and weight of each, or refer to Master 1.1e in their JASON Project journals. Point out the thrusters on each ROV and ask students to hypothesize which would accelerate faster in the water.

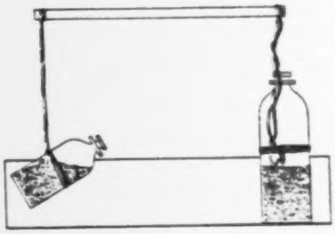
TEACHER TAKE NOTE

JASON's and JJ's thruster motors are the same size, but JJ's thrusters have smaller propellers which can turn faster and move more water. The two ROVs generate approximately the same amount of thrust, but because JJ has only a tenth as much mass as JASON, it accelerates faster and is more maneuverable.

4. Explain that JASON was well suited for the previous missions because of its stability and its ability to carry heavy equipment for making sonar images and photo mosaics. On this expedition, JJ will be photographing active marine life near Punta Espiñosa. Maneuverability and cost will be more important than stability.

5. Divide the class into working groups of four to six. Distribute rubber bands and two empty bottles to each group and give these directions:

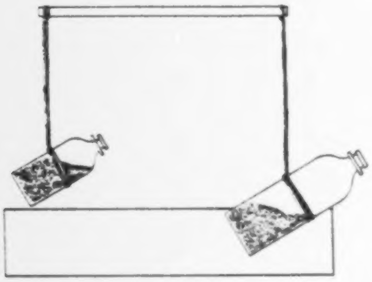
- Wrap one rubber band around the first bottle. Attach three or four rubber bands to the band already in place. Repeat with the second container.



- Attach the free ends of the two rubber band chains to opposite ends of a meter stick.

- Put the bottles on the floor. Lift both of them simultaneously by lifting the stick with a smooth, rapid motion. Observe how far the rubber bands stretch and the amount and speed of oscillation of the bottles. Record observations.

- Fill the containers with water and repeat the lifting. Record observations for the second trial.



6. Explain that the more mass an object has the more slowly it will accelerate when the same amount of force is applied. Ask students: What other factors might affect acceleration and speed of an ROV? (Answers may include size, shape, and surface area.) Challenge students to give examples from their own experience. Explain that engineers must take all of these factors into consideration when designing ROVs.

C. Conclusion

Pose the question: Is bigger necessarily better? Stress the point that technology constantly adapts to meet changing needs and requirements. Dr. Ballard has decided that a smaller, more maneuverable ROV can do a better job than JASON on the Galápagos expedition.

Adaptations

For younger students

Distribute copies of Master 2.2a and colored markers of two widths. Direct students to color the ROVs, using the type of marker that is most appropriate for each portion of the drawing. After students have been working for some time, help them to observe that one type of marker works well for coloring thin lines and one works well for coloring thick lines. Compare their choice to Dr. Ballard's choice between JASON and JJ.

For older students

1. Vary the procedure by placing the bottle in water, then dragging them through the water. Record observations as in step 5.

2. Put approximately 300 mL of sand into each container so they weigh the same (i.e., have the same mass), then repeat the experiment in water. This will point out the effect of surface are independent of mass.

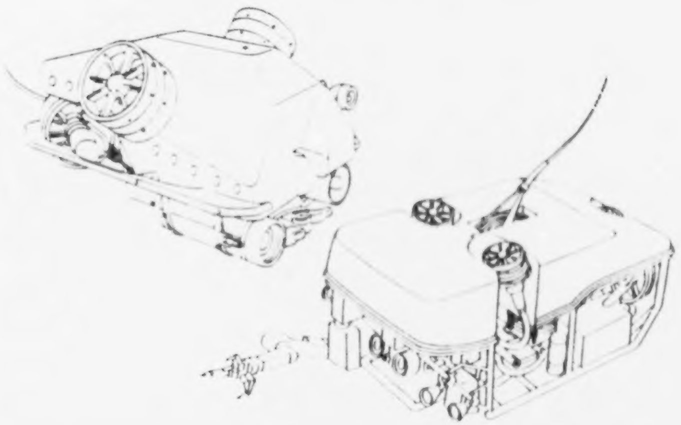
3. In step 5, substitute food packages of the same weight with different shapes and sizes. Discuss the results.

4. Challenge students to find out how JJ's propellors affect its speed and maneuverability, then set up experiments to test propellers of different sizes and conformations.

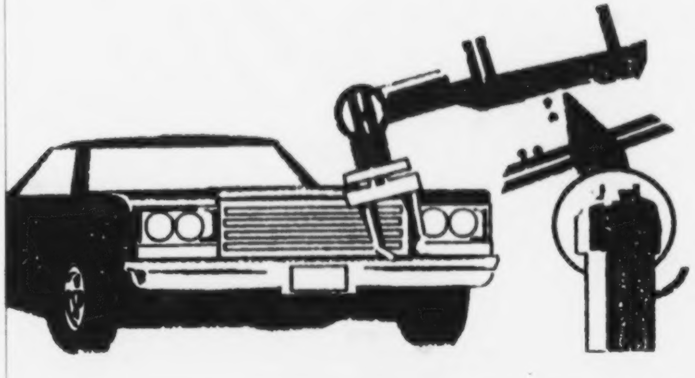
MASTER
2.2a

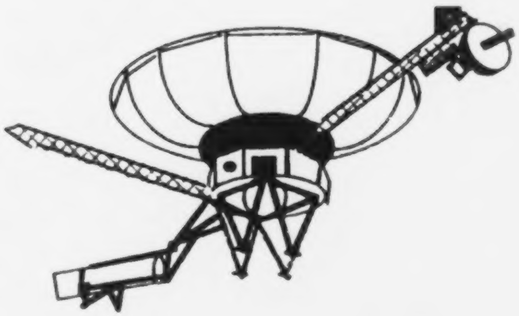
Kinds of Robots

JJ and JASON

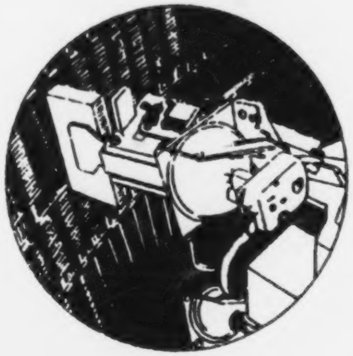


GM Factory Robot





Voyager 2



EDS Automated Tape Cartridge System

Back of Master 2.2a

Teacher Background Information

Kinds of Robots

Robots perform a wide range of functions in modern industry and public service. Students may think of robots as playthings or mechanical butlers, but working robots are usually designed to perform tasks too tedious, too precise, or too dangerous for human beings. In space, at the bottom of the ocean, or in a paint booth engulfed in toxic fumes, robotic machines can keep going without oxygen and at temperatures too high or too low for humans. Robots can be sent into dangerous places and controlled from a safe distance by a human operator. Robots can fight fires and can be used for bomb disposal work or for sweeping mine fields.

To do their jobs without the constant supervision of humans, robots must be controlled by computers which have memory units and systems to receive information. Humans program the computer with a set of instructions that tells the computer what to do with the information it receives and stores. Under the guidance of the program, the computer gives step-by-step, detailed instructions to the robot, and the robot then performs its tasks.

Some robots are programmed to vary their motions in response to stimuli, while some (called "bang-bang" robots) have their mechanical movement stopped at either end of their range by fixed blocks. They bang the fixed block at one end of their path and then bang the fixed block at the other end. The data center tape-cartridge robot shown on the other side of this page "sees" the correct cartridge by means of a camera and two lights mounted on each "hand." The robot takes the cartridge from its slot on the rack, moves it to the tape reader, and mounts it—all in 11 seconds.

JJ is a special type of robot, called a remotely operated vehicle (ROV), that takes its commands from human operators at a distance as well as from computer navigation programs. JJ's operator on the *Tohalli* will direct its movements from the command control panel by maneuvering a joystick that controls the robot's thrusters. A few students at the museums may also have a chance to operate JJ, within a designated field, by using a joystick.

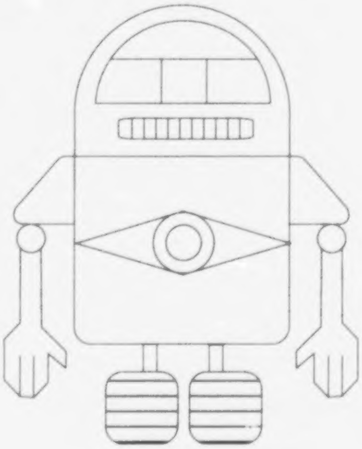
Robotics Worksheet

Look at the list of seven pairs of characteristics below. Write each characteristic in one of the spaces under HUMANS or ROBOTS as you think appropriate.

1. Strong	Fragile
2. Never get tired	Get tired
3. Never get bored	Get bored easily
4. Creative	Not creative
5. Dependable	Not always dependable
6. Adaptive	Not adaptive
7. Good at problem solving	Cannot solve problems

HUMANS	**ROBOTS**
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

What kinds of jobs do you think robots are good for?



What kinds of jobs are humans better for than robots?

MASTER
2.2c

Robot Specifications

Programming a robot to do even a simple task is not as easy as you might think. Your team is going to write a set of instructions to program a robot to set a table.

Not all robots are alike. The specifications for your robot are given in the list below. Pay special attention to the limitations of your robot.

ROBOT SPECIFICATIONS

Limitations

Robot *cannot*

- Learn
- Think
- Talk
- Sense pressure on an object (WARNING: Robot will crush fragile object unless it is commanded to stop.)
- See objects (you may want to blindfold your robot)
- Tell the difference among cup, plate, spoon, napkin, fork, and knife
- Use both arms to follow commands

Capabilities

Robot *can*

- Use one arm for commands
- Use the other arm to indicate errors
- Rotate at the wrist and shoulder
- Move a specific number of centimeters, meters, and degrees if preceded by a number
- Stop movement to avoid damage to environment or self
- Operate if it receives codes or commands in proper order:

Identification code. Action command (RBT STP)

OR

Identification code. Information code. Action Command (RBT 2M FD)

- Recognize and respond to the listed codes and commands

Identification Codes

RBT – ROBOT (BODY)

MOPR – MANUAL (VOICE) OPERATION

ARM – ARM

WRST – WRIST

HND – HAND

Information Codes

DGR – DEGREES

CM – CENTIMETERS

M – METERS

ERR – ERROR

Action Commands

ON - POWER ON

OFF - POWER OFF

STR - START

STP - STOP

LT - LEFT

RT - RIGHT

FD - FORWARD

UP - UP

DWN - DOWN

CLS - CLOSE

OPN - OPEN

ERS - ERASE

HME - HOME

INSTRUCTIONS FOR ROBOTS

All commands given to you must be followed specifically and literally. You cannot *interpret* any command. You cannot follow any command using words you do not know. Display the error card in such cases. If you receive the command to walk forward (RBT FD) you should walk straight ahead and not stop until told to, even though you know the results will be incorrect. Be certain you know all the commands in the ROBOT SPECIFICATIONS.

SATELLITE COMMUNICATIONS

2.3

ACTIVITY ONE

The Transmission System

Rationale

Today's communications technology makes it possible to view exploration as it occurs, whether in the oceans, in far away lands, or in space. The JASON Project telecommunications system uses audio, video, and data signals, linked and altered by computers, and sent via satellites. The system enables scientists to communicate with students and other scientists around the world.

Objectives

Students will:

Identify the major components of the JASON Project telecommunications transmission system.

Label the kinds of signals being sent among these components.

Simulate sending and receiving signals in a telecommunications system.

Materials

- Chalkboard and chalk
- Transparencies and student copies made from Master 2.3a, JASON Transmission System (two pages)
- Overhead projector
- Teacher information on the back of Master 2.3a, JASON Transmission System
- Transparency made from Master 2.3b, The Electromagnetic Spectrum
- Colored pencils, pens, or crayons
- Overhead projector
- Colored markers for the overhead
- TV set or VCR with remote control device
- Mirror
- Flashlight

VOCABULARY

De•crypt - to decode or "unscramble" a coded telecommunications signal.

Down•link - the transmission signal from a communications satellite that is received by a station on Earth.

En•crypt - to code or "scramble" a telecommunications signal in order to limit access to it.

Net•work - a series of communications devices arranged to pass information back and forth; all the interdependent parts of the communications system including the uplink and the downlink.

Sa•tel•lite - an object that orbits around a larger object.

Trans•mis•sion - the act of sending information in the form of signals or waves.

Up•link - a transmission signal sent to a satellite from an Earth station.

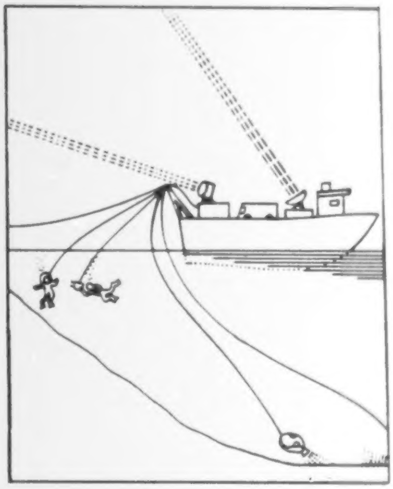
Teacher Preparation

Before class, use the background materials on the back of Master 2.3a to review the functioning of the JASON Transmission System.

A. Introduction

Ask students to name some familiar examples of how signals are used to transmit information. Most will name television (video) and radio (audio). Be sure students are able to distinguish between the incoming signals (energy in the form of waves, which we cannot hear or see), the receiver (the radio or TV), and the transformed signals (sound and/or images) that inform or entertain us.

B. Lesson Development



1. Project the first page of Master 2.3a, JASON Transmission System. Point out the major components at the site of the transmission, the scientists with cameras on land and in the water, and to the remotely controlled robot Jason Jr. (JJ). Draw an arrow to represent the data pathway down to JJ, explaining that this data signal tells JJ which way to move and where to point its cameras and other equipment.

2. Distribute the student copies of Master 2.3a, JASON Transmission System. Describe the function of each of the components corresponding to the numbers on the master. Point to each as you describe it.

3. Project the second page of Master 2.3a. Trace the path of the signals from the Galápagos Islands that transmit what the scientists observe. Mark the pathway from a satellite to the downlink sites on the transparency, using arrows of two different colors for the audio and video signals.

4. Demonstrate how signals can be used to control objects at a distance. Hold up a flashlight and a TV or VCR remote control device. Explain that each device emits a signal: the flashlight emits a visible light and the remote control emits an invisible infrared signal. Project Master 2.3b, The Electromagnetic Spectrum, and point out the visible, infrared, and microwave bands.

5. Point the remote control toward the TV and turn the set on and off. Ask:

- Did you see the signal? (No.)

- Did you see its effect? (Yes.)

Turn on the flashlight and point it toward the TV. Ask:

- Did you see the signal? (Yes, the beam of light is visible.)

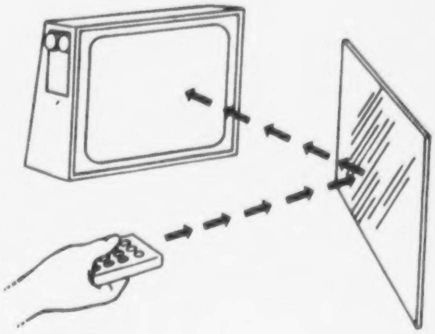
- Did you see its effect? (No.)

- Why didn't the flashlight turn on the TV? (Its signals are on the wrong band of the electromagnetic spectrum.)

6. Ask the students to predict what will happen if the remote control is pointed in another direction, away from the TV. Test the predictions. (Nothing happens to the T.V.)

7. Pose this question: If the remote control were pointed away from the TV and could not be turned around, what

could we do to make it turn on the TV? Unless someone answers correctly, ask a follow-up question: How can the direction of a wave or signal be changed? Hold up the mirror and ask students how it could be used to redirect light. Invite volunteers to explain or demonstrate how a beam of light (from the sun or from a flashlight) can be reflected off the surface of a mirror. Ask: Can the reflected beam be aimed at precise targets? Demonstrate by aiming the flashlight's beam at a mirror so it is bent back to hit the dark television screen. (You may have to shut off the lights so students can see the beam.)



8. Ask: Can the remote control's invisible, infrared signal also be reflected off the mirror? Demonstrate. Point the remote control away from the TV and click it on and off. Nothing will happen. Place the mirror in front of the remote control and position it to reflect the signal directly towards the TV's control panel. Click it on and off. The TV will go on and off.

9. Send the remote control's infrared signal and the flash light's visible light signal at the same time, reflecting both off the mirror. Point out that you are using one system to send two different types of signals.

10. Explain that a satellite is used in a manner similar to our use of the mirror to receive and transmit signals. The mirror, however, merely reflects our signals. A satellite can be equipped with electronic devices to receive, amplify, and rebroadcast the signals. For example, the microwaves carrying the audio, video, and data signals from the Galápagos Islands are amplified by satellite and sent back to Earth. Furthermore, a computer can scramble (encrypt) the signal it sends, so that only units equipped with special decoding devices can unscramble the signal. Thus technology controls who can receive the message. Messages sent by the JASON scientists and JJ's equipment are scrambled by computers aboard the ship before they are sent. Museum computers receive the signals and unscramble them. Home cable television companies also scramble their signals, so that subscribers must pay for devices to unscramble the incoming signal.

C. Conclusion

Again project both pages of Master 2.3a, JASON Transmission System. Ask students to point out:

- signal sources and signal types (scientists on land and under water, with cameras and JJ sending video, audio, and data signals in some combination).

- the uplink components (the shipboard uplink and the satellite uplink truck).

- the downlink components (Atlanta downlink and museum downlink).

- components used to redirect and amplify signals (satellites).

- components used to alter the signals (shipboard computers, satellites, Atlanta computers, and other equipment).

Adaptation

For older students

Challenge students to:

- set up a working system using more than one mirror.

- design and test a simple written code for scrambling and unscrambling data.

ACTIVITY TWO

Telepresence

VOCABULARY

Tel•e•pres•ence - the sense of "being there" conveyed by video images of scientific exploration.

Rationale

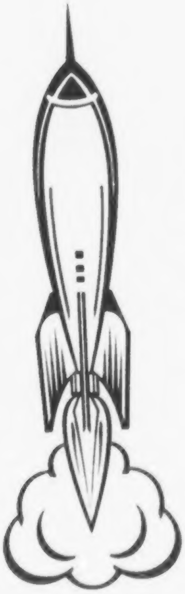
The technology of the JASON Project sets it apart from all earlier explorations. Students need to understand that today's communications technology makes it possible to view exploration as it occurs.

Objectives

Students will compare the transmission of knowledge in the JASON Project to that in other explorations.

Materials

- Student copies of Master 2.3c, Explorer Time Chart
- Student copies of Master 2.3d, Spotlight on Explorers
- Ruler or other straightedge for each



Procedure

A. Introduction

Ask students to think about how today's communications technologies make contemporary explorers different from explorers of the past. How much faster is information getting to the world through the JASON transmission than did Columbus's news of reaching what he believed to be Asia?

B. Lesson Development

1. Invite students to guess how long it will take the picture from JJ to reach the display screen so they can see it. (about a half second) The speed of transmission is the speed of light, which is 297,600 kilometers per second, or 186,000 miles per second. Ask:

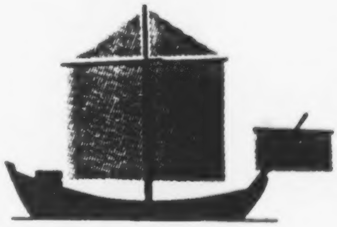
- How long did it take Columbus to tell the people at home what he had found?

- How long did it take other explorers to report their discoveries?

- Does it make any difference that we can see a discovery being made, rather than hearing someone tell about it, or reading about it later in a book? (Relatively few people actually travel to any one site, especially if it is remote. This limits knowledge at the site to the expertise of those present. With many scientists and observers viewing simultaneously, much experience and skill can be brought to the scene of the exploration. This means better questions, better conclusions, and better decisions on what to look for next. The scientists can look further and explore more hypotheses while still at the exploration site.)

- If an explorer finds something important that no one back home has seen before, and can't get home to tell anyone, is the new discovery really made? How important is communication? (For instance, were there early European explorers who discovered North America other than Leif Ericson and Christopher Columbus?)

2. Hand out copies of Master 2.3c, the Explorer Time Chart, and Master 2.3d, Spotlight on Explorers. Ask students to read the accounts of famous explorers, choose five from the master, and list them on the chart in order from the longest ago to the most recent. Have students use their rulers to extend a straight line from Month 1 to the approximate time it took to bring home the information. In some cases they will have to make guesses based on what they know about the technology that was available at the time.



3. In a class discussion, compare the time it took different explorers to relay information to the rest of the world. How long did it take for the next person or group to get to the same place or see the same thing? What did they have to wait for? Point out the significance of telepresence—the fact that we don't have to wait for the information to be relayed. Discuss the times involved in waiting for:

- The next voyage.
- The next troubadour.
- The next stagecoach.
- Printing to be invented.
- The pony express to deliver the mail.
- The mail carrier or express mail service.
- The film to be developed.
- The videotape to be flown to the TV studio.
- The next space shuttle.

C. Conclusion

Invite students to learn more about one of the early explorers mentioned, or one who was not mentioned, such as Amerigo Vespucci or Matthew Henson. They may want to include other types of explorations, such as William Harvey's discovery of the circulatory system, or other discoveries that expanded our knowledge, such as Marie Curie's discovery of radium. What other kinds of explorers have there been? What new fields that didn't exist a few years ago might students be exploring as adults?

ACTIVITY THREE

Geosynchronous Satellites

Rationale

Communications satellites, like the ones that will bring the JASON transmissions to the downlink sites, move in geosynchronous orbit.

Objectives

Students will:

Discuss the satellite transmission technology used in the JASON Project.

Describe some properties of geosynchronous orbits.

Materials

- Transparencies made from Master 2.3a, JASON Transmission System
- Transparency made from Master 2.3e, Kinds of Satellites
- Transparency made from Master 2.3f, Geosynchronous Orbit
- Overhead projector

Procedure

A. Introduction

Project Master 2.3a, JASON Transmission System, and review the components. Point out the communications satellite. Explain that satellites have different functions and that where they are placed in orbit relates to the work they have to do.

B. Lesson Development

1. Project Master 2.3e, Kinds of Satellites, and read the material on the back of the master to students. Discuss the kinds of satellites. Stress that the two satellites pictured on Master 2.3e are communications satellites.

2. Explain: A satellite is a body that orbits, traveling in a fixed path, around another body. Arthur C. Clarke is usually credited with the concept that made modern communication satellites possible. In 1945 he described the special kind of orbit that is essential to communications satellites—geosynchronous orbit. Define the term by breaking it into its components:

Geo = Earth

Syn = with or together

Chronos = time

Geosynchronous = in time with the Earth's rotation

3. Project Master 2.3f, Geosynchronous Orbit. Point out the orbiting satellite and ask students to note how far it is from the Earth. Ask: Does it matter how far the satellite is from the Earth? (Arthur C. Clarke calculated that an object launched 36,000 km [21,600 miles] into space and moving above the equator at the proper velocity (22,000 km/hr or

VOCABULARY

Es•cape ve•loc•i•ty - the speed an object must attain to escape from the Earth's gravitational force.

Ge•o•syn•chro•nous - moving at the same speed as the Earth's rotation, so that it appears to be standing still.

Grav•i•ty - the attractive force between the Earth's mass and the mass of objects at or near its surface.

Sat•el•lite - a body that orbits, traveling in a fixed path, around another body.

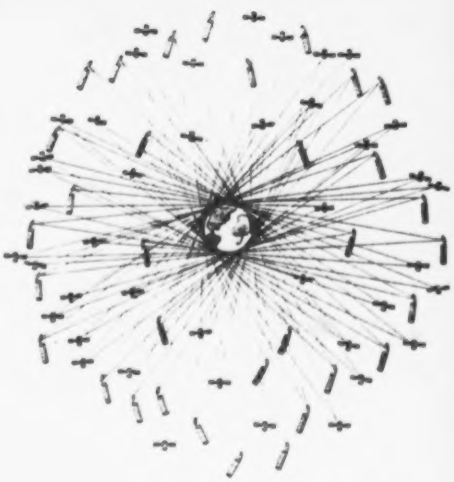
TEACHER TAKE NOTE

Students may recognize Arthur C. Clarke as the author of *2001: A Space Odyssey*.

13,200 mph) could circle Earth in the same period of time as the Earth takes to rotate. From any position on the Earth's surface the satellite would appear stationary.)

4. Ask: Can we see these geosynchronous satellites? (It depends on their size, their distance from the Earth, whether their surface is shiny [reflective] or dull [nonreflective], and the weather. Geosynchronous satellites are the hardest to see. Because they appear stationary, they look like dim stars.)

5. Ask students to guess how many satellites there are in orbit around the Earth. They will be amazed at the answer—approximately 2000 satellites in orbit as of May 1991 according to NASA sources.



C. Conclusion

Have students hypothesize about why so many satellites are in orbit. What are their functions? (Have them refer to the back of 2.3e, Kinds of Satellites.) What are some considerations to make when placing new satellites in orbit?

ACTIVITY FOUR

Simulating Orbits

Rationale

The proper relationship between the altitude and the velocity of a satellite makes satellite communications possible.

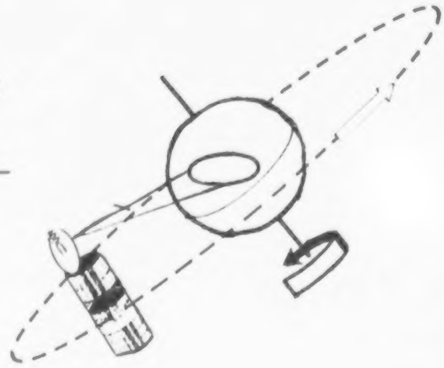
Objectives

Students will:

Simulate a geosynchronous (stationary) orbit.

Simulate the relationship between velocity and the altitude of orbits.

Describe some properties of orbits and the effect that changing the radius of its orbit would have on the speed of a satellite.



Materials

- Small Nerf™ ball
- 1 meter (about a yard) of elastic cord
- Student copies of Master 2.3g, Revolution Times of Satellites Worksheet (*optional*, for adaptation)
- Transparency made from Master 2.3h, Distance Chart (*optional*, for adaptation)
- Overhead projector (*optional*)

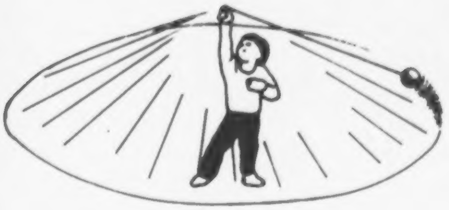
Procedure

A. Introduction

Explain that the closer a satellite is to the surface of the Earth, the faster it must travel to stay in orbit. A satellite at 320 km (192 miles) above the Earth (high enough to be above most of the atmosphere, which would slow a satellite) must orbit the Earth at about 22,000 km/hr (13,200 mph). At this speed the satellite would orbit faster than the Earth's rotation, and would appear to be moving around the Earth relative to an observer standing still on the Earth's surface. At an altitude of about 36,000 km (21,600 miles), a geosynchronous satellite appears to stand still but really moves at a speed of 11,000 km/hour (6,600 mph). At that speed and altitude the satellite makes one orbit of the Earth every 23 hours and 56 minutes, which moves it along in synchrony with a stationary observer on the Earth.

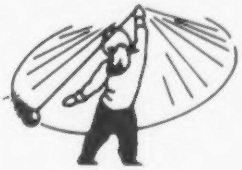
B. Lesson Development

1. Tie the elastic cord around the ball just tightly enough to stretch the elastic and make a slight indentation in the ball.



2. Clear a large area in the center of the room, or take students outdoors or to the gym. Have a volunteer swing the ball "satellite" above his or her head. Ask the class to observe the speed of the ball at the end of the cord.

3. Instruct the volunteer to wind up one third of the cord and repeat the swing, then to wind it up again so only a third of the original length remains and swing again. Ask students what difference they observe. (The closer the ball is to the pivot point—the swinger—the faster it has to move to stay horizontal.) Emphasize this conclusion: The more the cord is shortened, the faster the ball must move to stay in orbit.



4. Explain: The hand holding the cord represents the Earth. The ball on the string represents a satellite that is constantly orbiting the Earth. The closer the satellite is to the Earth, the faster it must move to remain in orbit.

C. Conclusion

Review the activity. The closer a satellite is to the Earth the stronger the Earth's gravitational pull, and the faster the satellite must move to avoid falling to the Earth. Low-Earth satellites orbit at about 28,000 kilometers per hour (16,800 mph). This speed carries them around the Earth in 1.5 hours. Communications satellites travel at 11,000 kilometers per hour (6,600 mph) and pass around the Earth in 23 hours, 56 minutes, the time of one rotation of the Earth. This is the relationship that Arthur C. Clarke discovered.

Adaptation

For older students

The distance from the surface of the Earth required for any period of revolution can be calculated and graphed. To graph without calculations pass out Master 2.3h, Revolution Times of Satellites, and project Master 2.3i, Distance Chart. Point out that the duration of one orbit (period) is the y-axis and altitude is the x-axis. Have students plot the altitude at 2, 5, 10, 15, 20, 25, and 30 hours. Join the plotted points with a smooth curve and interpolate to determine the altitude required for 23 hours and 56 minutes.

ACTIVITY FIVE
Parabolic Dish Receivers

Rationale

Parabolic dish receivers bring the JASON Project transmissions from the Galápagos to the museums where students and teachers will participate.

Objective

Students will describe the role of parabolic dish receivers with respect to the JASON Project's satellite transmission system.

Materials

- Transparencies made from Master 2.3a, JASON Transmission System
- Transparency made from Master 2.3i, Satellite Footprints

Procedure

A. Introduction

Project Master 2.3a, JASON Transmission System, and point out the antennas: the uplink on board the ship, the downlink at the Atlanta transmission station, and the downlinks at the reception sites. Explain: All these parts together are called the network. The network manager is responsible for seeing that everything works together, that the signal is being sent to the right satellite "channel," and that the signal is being received by the downlink dishes at the reception centers.

B. Lesson Development

1. Project Master 2.3i, Satellite Footprints. Ask students to describe what they see. Explain: A satellite's transmission to Earth is a form of radiated energy. Much like a flashlight, which can radiate light energy to a particular spot, a satellite can send a signal to a specific area. A geosynchronous satellite is stationary relative to a given point on the Earth, so it will always send to the same area. This area is called its footprint. A satellite's transmission to Earth, even though tightly focused, puts only a very small amount of energy in any one place—the signal has to come across almost 36,000 km (21,600 miles) and spread out across a continent.

2. Explain that satellite dishes (Earth station receivers) are antennas that function in much the same way as radio antennas. Dishes are different from radio antennas, however, because they help focus and concentrate incoming energy in a particular area. The feedhorn, located in this area of most concentrated energy, holds the actual antennas, each less than 2.5 cm (an inch) long and about the diameter of a pencil. The reflector dish, which is parabolic in shape, focuses the signal toward the feedhorn. Dishes can be rotated horizontally (left to right) as well as vertically (head to foot). The network managers position the dish to aim at the proper satellite. They can "tune in" several stations on the satellite, but no one else can receive the JASON transmission because it is encrypted, or "scrambled," like the signals on the pay TV

VOCABULARY

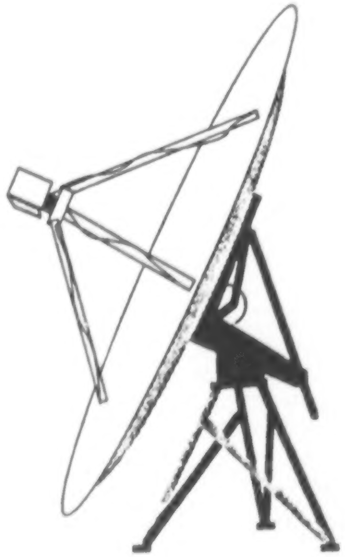
Feed•horn - section of a satellite receiver at which a concentrated signal is focused by the parabolic dish.

Foot•print - elliptical area on the surface of the Earth within reception range of a satellite.

Net•work - a series of communications devices arranged to pass information back and forth; all the interdependent parts of a communcations system including the uplink and down link.

Par•a•bol•ic - bowl-shaped.

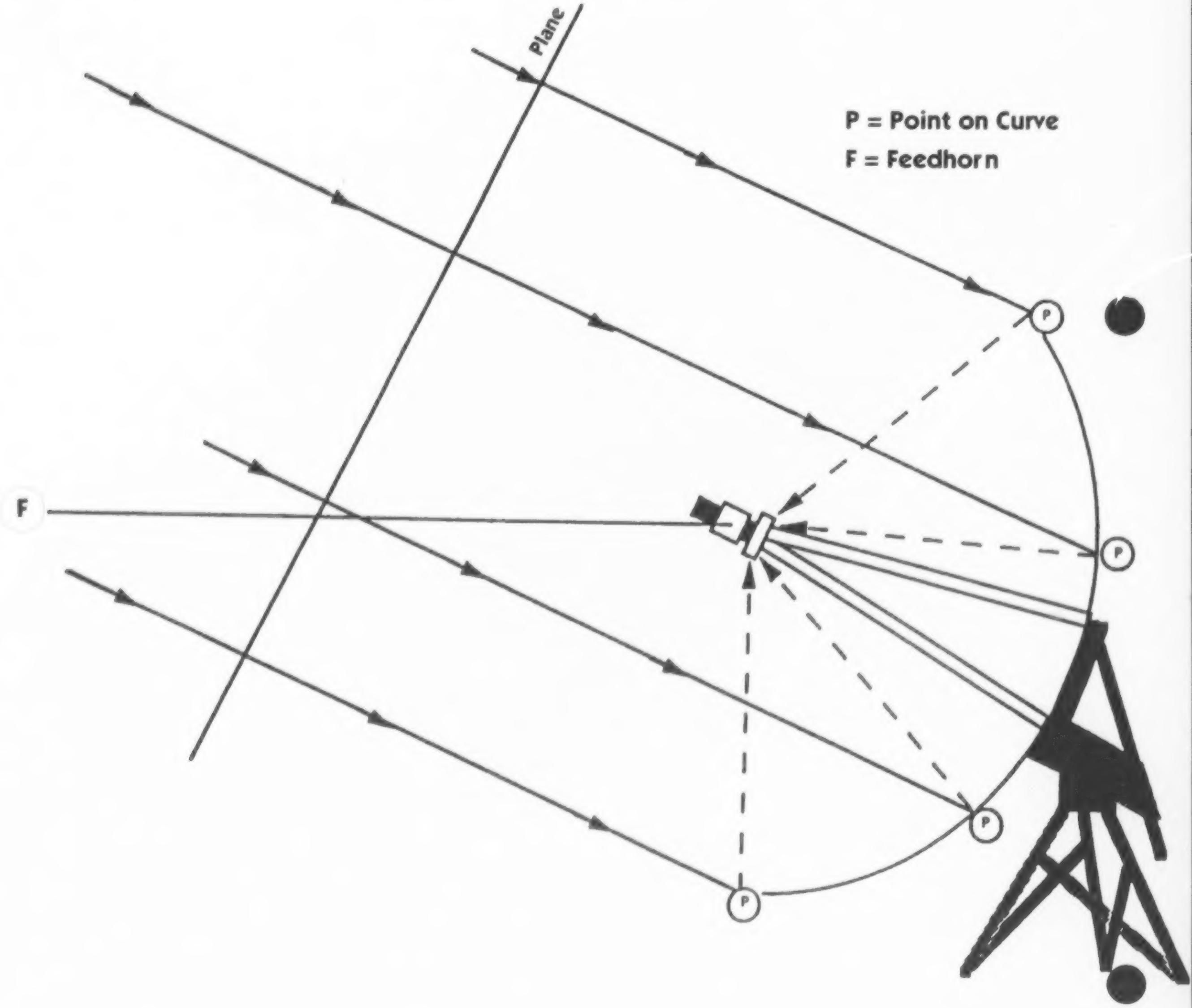
Per•iod - the duration of an orbit; the time required for an object in orbit to return to its starting point.



channels. The network managers encrypt outgoing signals so that only the reception sites (which have the equipment) can decrypt, or "unscramble," the JASON message.

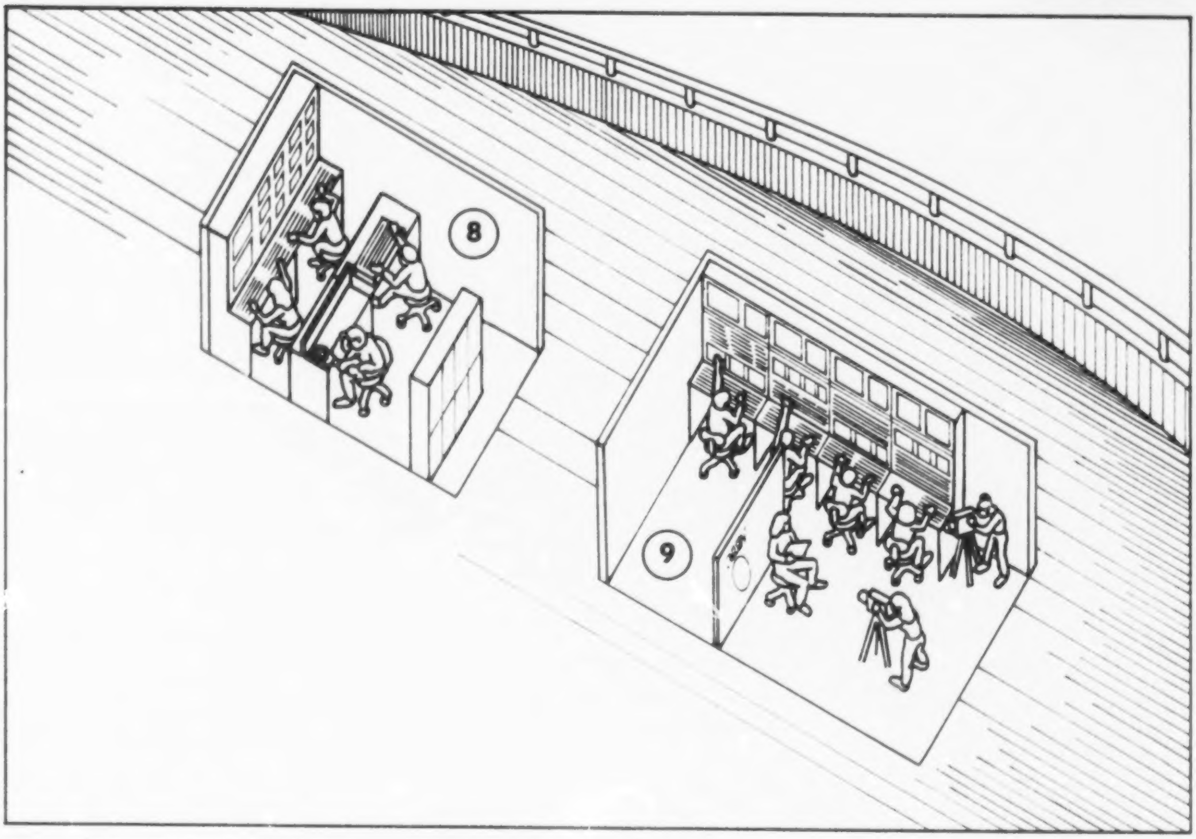
C. Conclusion

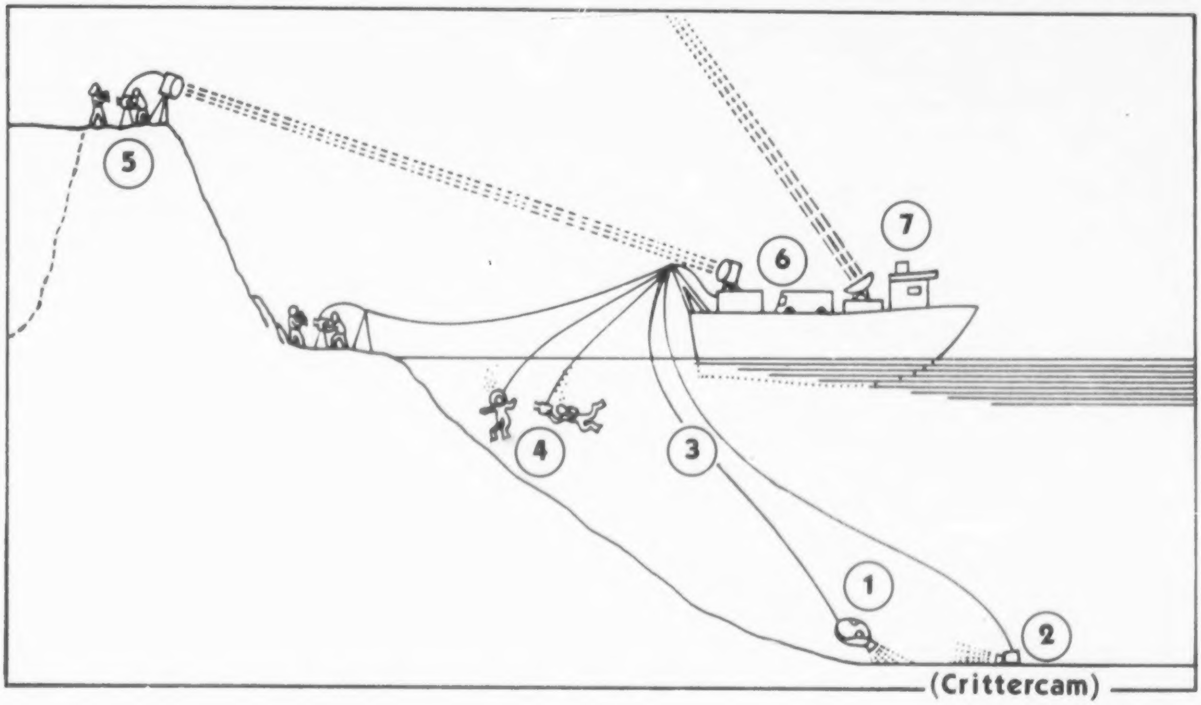
Draw the parabolic curve illustrated below on the chalkboard. Explain that energy from the uplink is concentrated in the feedhorn; when focused onto the parabolic curve it is radiated out in parallel paths. The parallel paths of energy are collected by the downlink parabolic curve and concentrated at the feedhorn where the antenna is located.



JASON Transmission System, Part I, Uplink

MASTER
2.3a




5
7
6
4
3
1
2
(Crittercam)

Back of Master 2.3a

JASON TRANSMISSION SYSTEM

Numbers 1–9 are found on Part 1, Uplink. Numbers 10–14 are on Part 2.

1. *Jason Jr.* (JJ) - This specially designed ROV system can be equipped with both color and black-and-white video and still cameras. Computers on JJ accept commands from scientists and send back sensor information (depth, heading, and position).

2. *"Crittercam"* - A fixed bottom camera at 91.5 meters (300 ft) supplements the cameras on JJ.

3. *Cable* - Cable carries two-way information between the shipboard control center and the exploration sites underwater, in shallow water, and on shore.

4. *Scuba Diver* - A scientist (Jerry Wellington) with a special bubble helmet is in voice communication with the ship as he interprets the underwater scene.

5. *Volcano* - Scientists and photographers on the rim of the caldera are in microwave communication with the ship.

6. *Ship Satellite Command Center* - Instruments encrypt signals, aim the uplink antenna at the correct satellite, tune in the correct transponder signal, and monitor the quality of the transmission.

7. *Ship Uplink* - Instruments receive scrambled video signals from the command center and transmit them to the satellite. The antenna is 2.1 meters (6.5 ft) in diameter, and is equipped with a gyro stabilizer that keeps it fixed on the satellite regardless of the motion or direction of the ship.

8. *Production Van* - The television crew works here. The video switchers and other production equipment operate from this shipboard van.

9. *JASON Control Center* - JJ's activities are operated and monitored from this center. It also serves as an onsite television studio, with cameras and camera operators.

10. *International Satellite* - Located 36,000 km (22,300 miles) above the equator, it receives the microwave signals transmitted by the shipboard uplink and sends them to the downlink antenna at the transmission station.

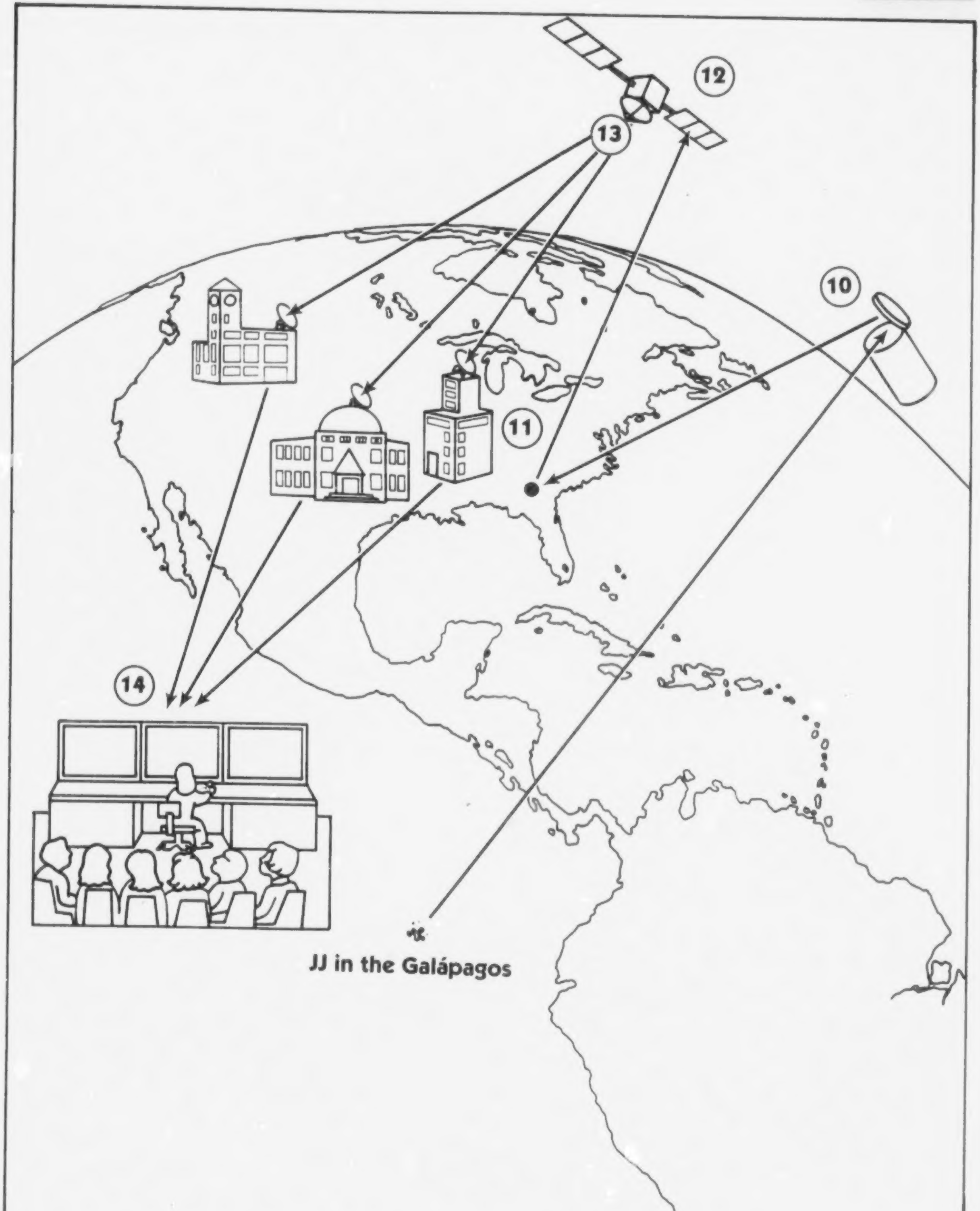
11. *Atlanta Downlink* - Atlanta receives the signal from the international satellite and retransmits it to the domestic satellite.

12. *Domestic Satellite* - This satellite relays the signal to the museum downlinks.

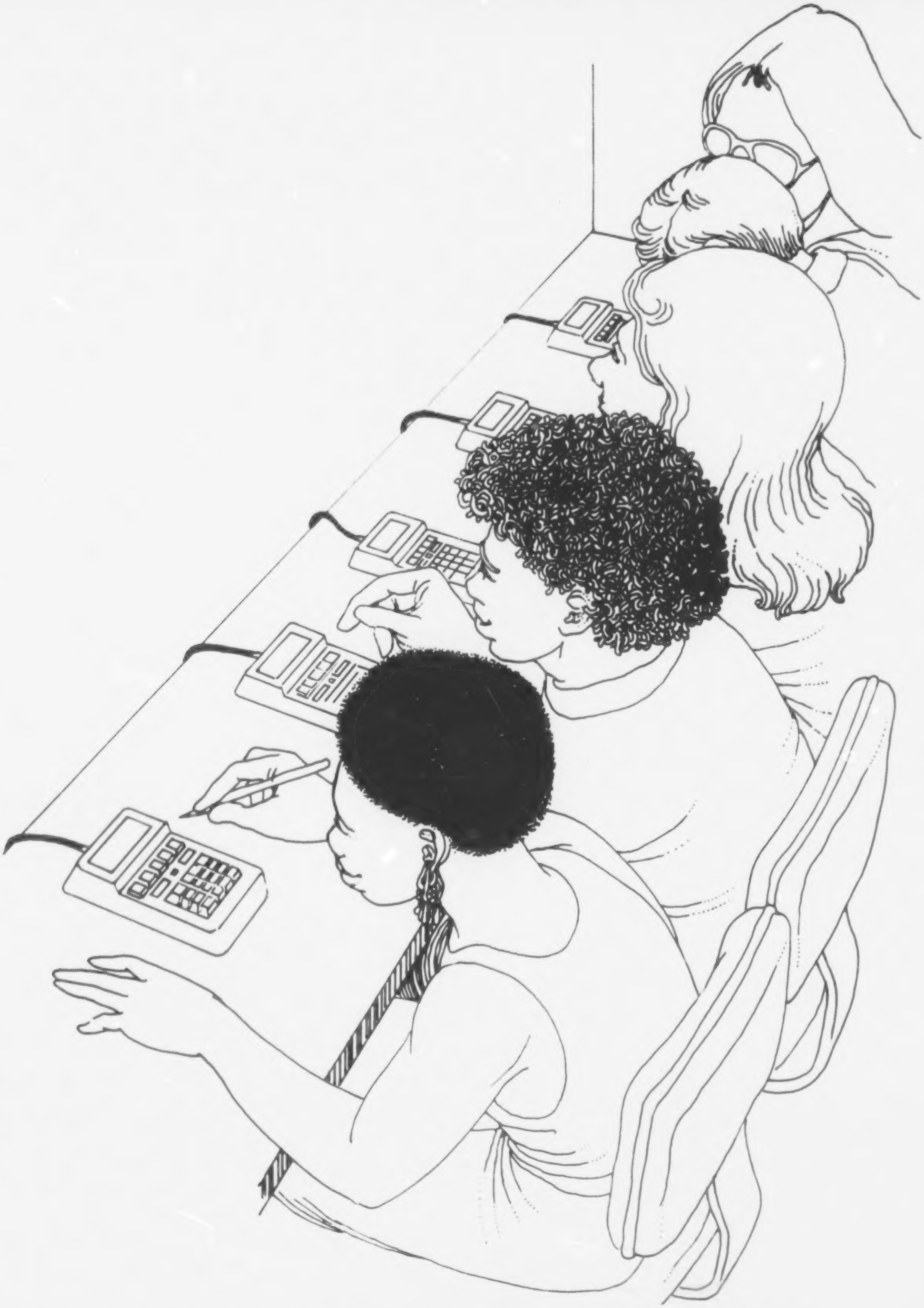
13. *Center Downlinks* - Parabolic dish antennas at each downlink site receive the signals from the domestic satellite and convert them back to audio and video for presentation at the reception centers.

14. *Reception Centers* - At each museum, university, or other center, three large-screen video projectors display the view through JJ's camera, along with images from the shallow water and land sites. Students at work stations like Dr. Ballard's may use a keypad to answer questions and a joystick to control JJ.

JASON Transmission System, Part II, Downlink


12
13
10
11
14
JJ in the Galápagos

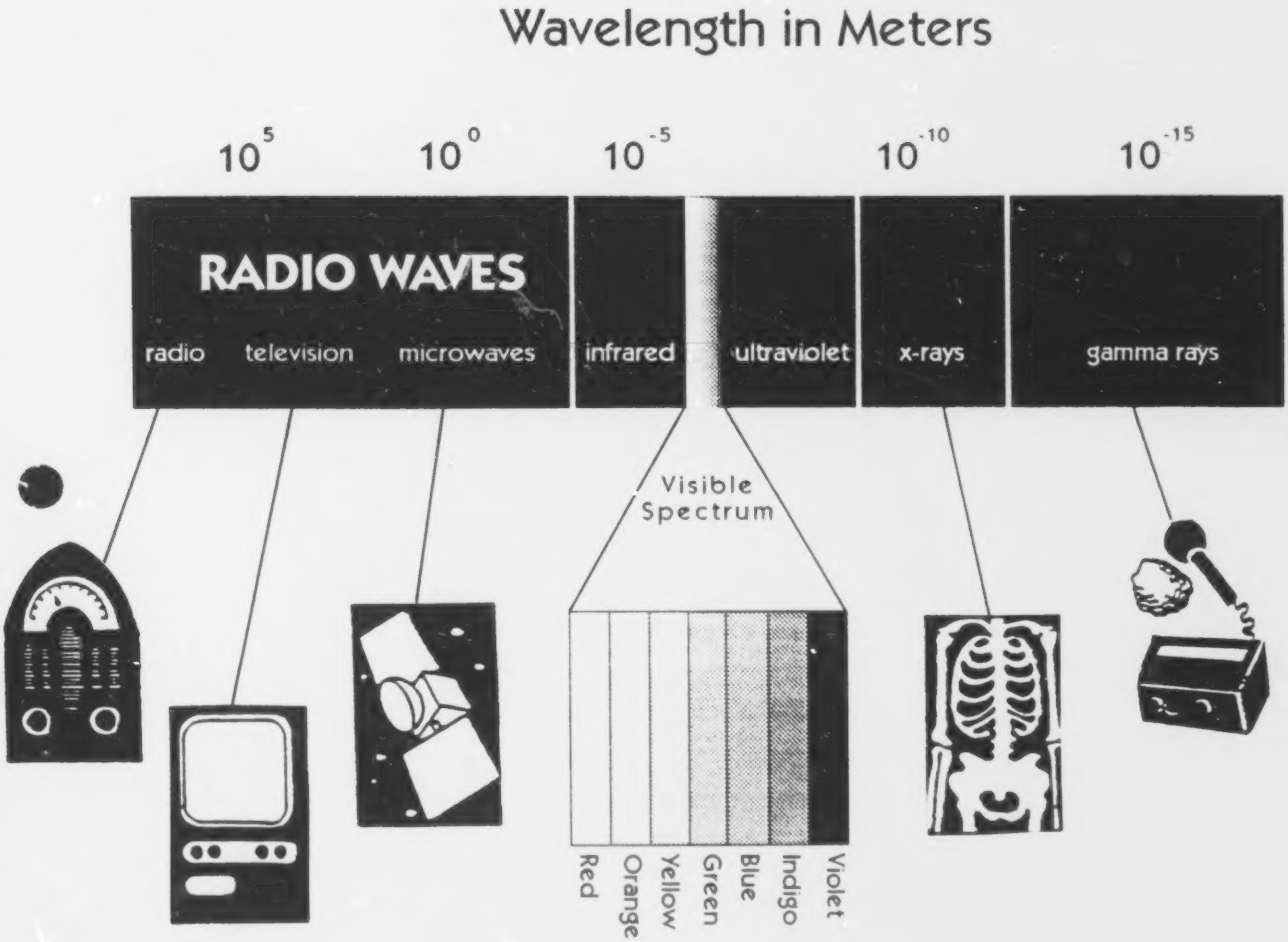
82



Some students at downlink sites will be able to use keypads to respond to questions asked by Dr. Ballard.

8.1

The Electromagnetic Spectrum


Wavelength in Meters
10^{5}
10^{0}
10^{-5}
10^{-10}
10^{-15}
RADIO WAVES
radio
television
microwaves
infrared
ultraviolet
x-rays
gamma rays
Visible Spectrum
Red
Orange
Yellow
Green
Blue
Indigo
Violet

MASTER
2.3c

Explorer Time Chart

NAME OF EXPLORER	Time To Return With News (In Months)																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Robert Ballard and Student	Immediately																									

Spotlight on Explorers

MASTER
2.3d

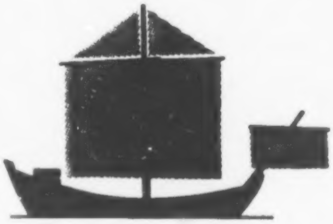
Imagine you are an explorer in earlier times. What tools would you use in your explorations? And when you made your discovery, how would you spread the news? The knowledge and the technology available to the explorers of any age determine the answers to these questions. The way they surmounted the limitations imposed by food scarcity, communications difficulties, and in the case of women, the limits set by society, defined their success as explorers. You and the JASON Project crew will see discoveries as they happen; but as you read about these explorers from the past you will note that it often took many years for their fellow citizens to learn of their discoveries.

Leif Ericson was the son of Eric the Red, the Norse discoverer of Greenland. Around A.D. 1000, sailing west from Greenland, he was driven off course by a storm. Ericson's ship landed in what is now called North America. He named the place Vinland because of the many wild grapes growing there. The crew took samples of the grapes to Greenland, along with wild grain, as proof that they had found a new land. Norse sailors made several more expeditions to Vinland, the last commanded by Leif Ericson's half-sister Freydis Ericson in A.D. 1014.

If Leif Ericson had headed directly home to tell the news, and had navigated successfully, the trip from Vinland (probably Newfoundland) to Greenland would have taken from one to two weeks, depending on the weather. People in the rest of Europe did not learn of Vinland for centuries because the story of its discovery was only told in the Norse sagas.

Marco Polo left Venice, Italy, at the age of seventeen with his father Nicolo Polo and his uncle Maffeo Polo. Their journey, beginning in 1271, took them to China for trade with the great Mongol ruler Kublai Khan. The Polos' three-year journey to China was one of the longest overland trips recorded during the Middle Ages. The Khan was greatly pleased with young Marco and made him one of his advisers, often sending him on official visits to different parts of the kingdom. Marco took detailed notes and learned about such things as paper money, the use of coal as fuel, and the Khan's postal system. After living in China (then called Cathay) for seventeen years, the Polos began their journey home to Europe. They had been gone for 24 years, and when they arrived in Venice no one recognized them.

The people of Europe learned about the Far East through Marco Polo's book *Description of the World*, published in 1298, twenty-seven years after the beginning of their journey. For hundreds of years Marco Polo's book was the main source of information about the Far East.



Christopher Columbus read Marco Polo's book when it was printed on the newly invented printing press, and it made him anxious to be the first person to find a direct route to the East. He wanted to travel entirely by sea, for the route taken by Marco Polo was too long and too risky. Columbus, like the sailors and the educated people of his time, knew that the Earth was a sphere. However, he believed that the world was much smaller than it is, and that Asia extended much farther to the east than it does.

It took nineteen years before Columbus found monarchs willing to back his expedition. Finally Isabella I and Ferdinand V of Spain agreed to sponsor him, and Columbus sailed from Spain on August 3, 1492. At two o'clock on the morning of October 12, 1492, one of the sailors on the *Pinta* sighted land. Before noon Columbus went ashore on an island in the Bahamas that he named San Salvador and claimed for Spain. He arrived back in Spain on March 15, 1493.

Columbus kept a ship's log and brought back Native American art, agricultural products, and exotic animals from the islands. He presented his gifts and reported his findings to Isabella and Ferdinand. Ultimately, Columbus made four voyages to the New World between 1492 and 1504.

In Columbus's time, sailors had the compass to help them find their way. They could figure latitude and see where they were on a map with the help of other simple instruments such as the astrolabe, the quadrant, and the cross-staff. They could not yet figure longitude. This accounts for Columbus's misunderstanding of how far west he had to go to reach Asia.

Ferdinand Magellan was the Portuguese navigator who finally crossed the Pacific Ocean and fulfilled Columbus's dream of reaching the Indies by sailing west. His three-year voyage proved that the Earth was round and that the "New World" was not a part of Asia, but instead two continents totally unknown to Europeans.

Magellan left Spain with five ships and 265 officers and crew in September 1519. He took one year to find a way around America through the passage we now call the Strait of Magellan. On November 28, 1520, Magellan entered the Pacific with three ships and no idea how vast the ocean was. It took three months for Magellan to reach the Philippines. By that time, the crew was suffering from starvation and scurvy, a disease caused by lack of Vitamin C. Bad luck denied Magellan the glory of completing the first trip around the world; he was killed in a tribal battle on a Philippine island. Only one of his ships and 18 sailors returned home to Spain, reaching port in 1522.

James Cook was a British navigator and one of the world's greatest explorers. His expeditions included three voyages to the Pacific Ocean and two voyages around the world. In 1768 he led a scientific expedition to Tahiti to look for a new continent in the South Pacific. He was the first European to visit New Zealand, landing there in October 1769. In April 1770 he sailed into Botany Bay and claimed the east coast of Australia for Great Britain. This first voyage ended when he returned to England in July 1771.

Cook's second voyage lasted from 1772 to 1775. He sailed to New Zealand again and crossed the Antarctic Circle. On his third voyage Cook reached the Hawaiian Islands and sailed to the northwest coast of North America. He went as far as the Bering Strait and entered the Arctic Ocean. On his return to the Hawaiian Islands he was killed by Hawaiian natives in a dispute over a stolen boat.

Lewis and Clark were the explorers hired by President Jefferson to report on the vast western land recently purchased by the United States from France. Sacajawea, the Native American woman who served as guide, led Lewis and Clark and the men of the expedition west across lands white men had never seen before.

William Clark and Meriwether Lewis sailed the Missouri River from St. Louis in the spring of 1804. They spent the winter in what is now North Dakota and crossed the Rocky Mountains in the spring of 1805. They continued their journey west by sailing down the Columbia River to the Pacific Ocean. Lewis and Clark came back to St. Louis in 1806, after covering eight thousand miles in two years with the loss of only one man. Their expedition studied the country, drew maps, and kept a daily journal of the wonders they had seen and the dangers they had overcome. Their report thrilled the American people and made many want to move to the new land.

In 1805, *Simon Fraser* was placed in charge of the North West Company's operation beyond the Rocky Mountains. He made a new settlement called New Caledonia, which is now Central British Columbia. He also established Fort George, which is now Prince George, British Columbia. In 1808, he started exploration of what he thought was the Columbia River. He soon discovered it was not and turned back. Later, David Thompson explored the same river and named it the Fraser River after Simon Fraser.

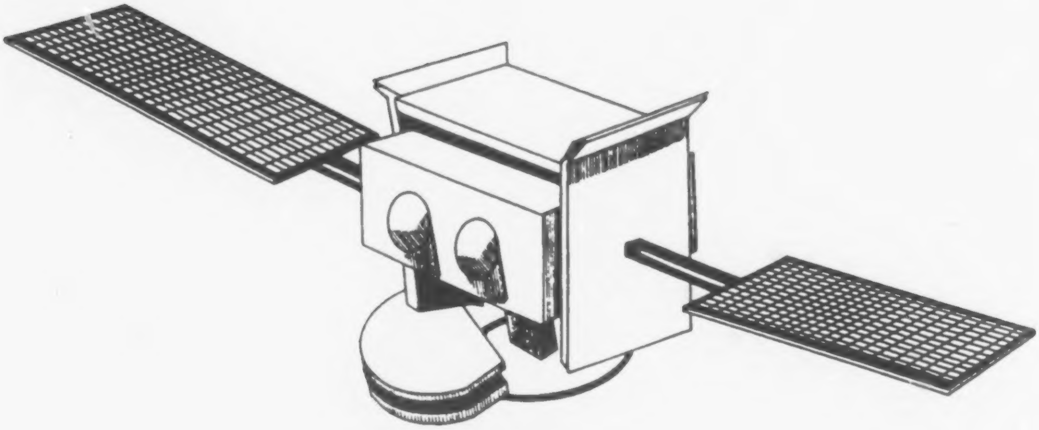
Maria Mitchell, born in 1818 on the island of Nantucket, discovered a new comet in 1847. In 1831, the king of Denmark had offered a gold medal to the next person who used a telescope to discover a comet. The news was immediately communicated by letter to the head of the Harvard University observatory and then to Denmark. Astronomers in Europe had also spotted the comet, but Mitchell's sighting was adjudged to be the first.

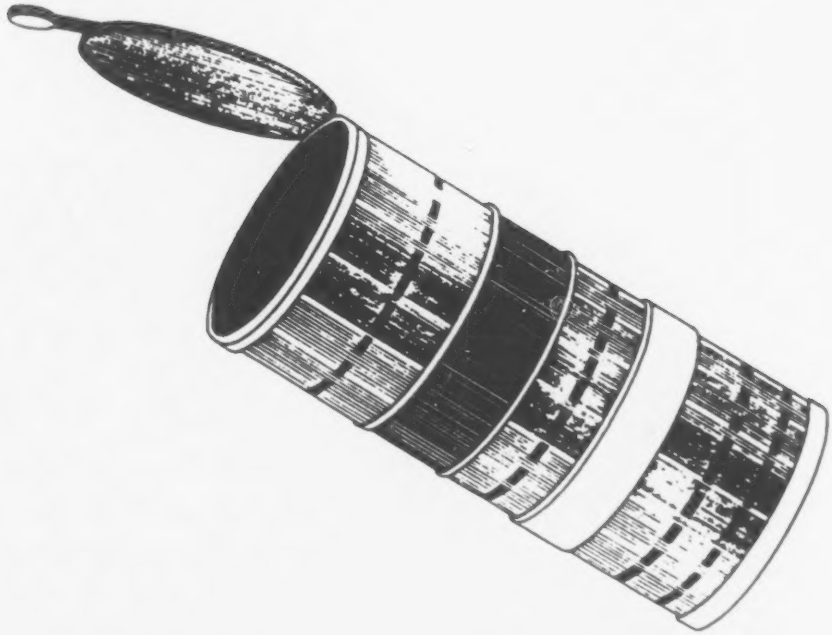
At a time when society dictated that women's lives be conducted within the confines of home and family, Mitchell became a double pioneer. She was not only the first professional woman astronomer in the United States, but also a leader in the movement to educate women at the university level. In 1865 she became Professor of Astronomy at Vassar College. There she was a strong advocate of a rigorous science and mathematics curriculum based on primary sources and original observation. In 1869 she led seven of her students on an unprecedented field-work expedition to Iowa to observe the total eclipse of the sun.

Richard E. Byrd was an American naval officer, explorer, and scientist. In 1925 he made the first of five explorations over the Arctic and the Antarctic. In 1926 he and Floyd Bennett made the first successful flight over the North Pole. Byrd had a bubble sextant and two sun compasses for navigation. Using this technology he was able to report "at 9:02 Greenwich Civil Time on May 9, 1926, our calculations showed us to be at the Pole." The flight was the first successful effort to use airplanes to explore the far North.

In Byrd's later expeditions he used the most modern equipment available to him and wrote several books about his discoveries. The world heard about Byrd's scientific discoveries within hours through radio transmissions, and they learned more over the succeeding months through photographs, print accounts, and scientific lectures.

Kinds of Satellites





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Back of Master 2.3e
Kinds of Satellites

Both satellites pictured can perform any of the following five functions—and probably many that we haven't yet considered. Both satellites illustrated on the front of the master will be used in the 1991 JASON transmission. The satellite illustrated in the upper portion of the master will serve as the domestic satellite and the can-like satellite will serve as the international transmitter.

Domestic communications satellites - These can relay radio and TV signals across oceans and continents. They can relay voice signals, allowing people to talk on the telephone with people in other countries. Communications satellites are geosynchronous; that is, they move in orbit as fast as the Earth rotates, so they are always over the equator. They can be used at all times, day or night. The satellites that enable us to see and hear JASON's transmissions are communications satellites.

Navigation satellites - Satellites guide ships at sea by sending out steady radio signals. Ships' computers use the satellite signals to check the ship's position and keep it on course. This function is called dynamic positioning.

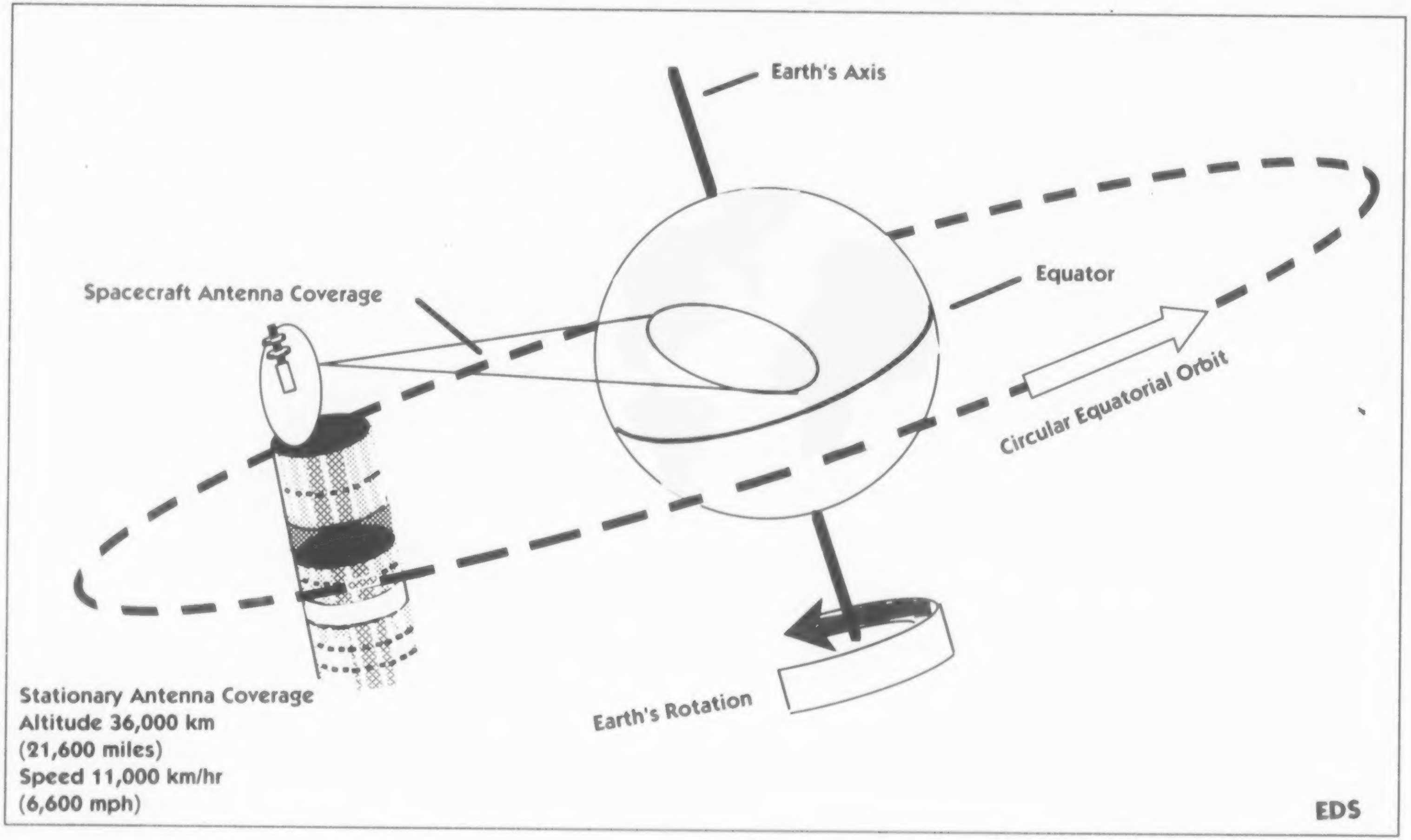
Observation satellites - Instruments in these geosynchronous satellites can pick out objects as small (when photographed from high in the sky) as buildings, or make maps of hard-to-reach areas. Even more sophisticated equipment attached to telescopes can show objects as small as books. These satellites help farmers identify crop problems before they are noticeable on Earth. They can identify ocean temperature differences, waves, and water currents. They can spot icebergs, and locate natural resources such as minerals.

Scientific satellites - These collect information that scientists can use to find out about the Earth, the Sun and other parts of our universe. Special instruments on board these satellites may measure Earth's magnetic forces, collect data about the atmosphere, or measure the energy from the Sun. Telescopes on board satellites can see stars much farther away than can telescopes on land, because they are outside the Earth's hazy atmosphere. They will help scientists answer questions about stars and outer space.

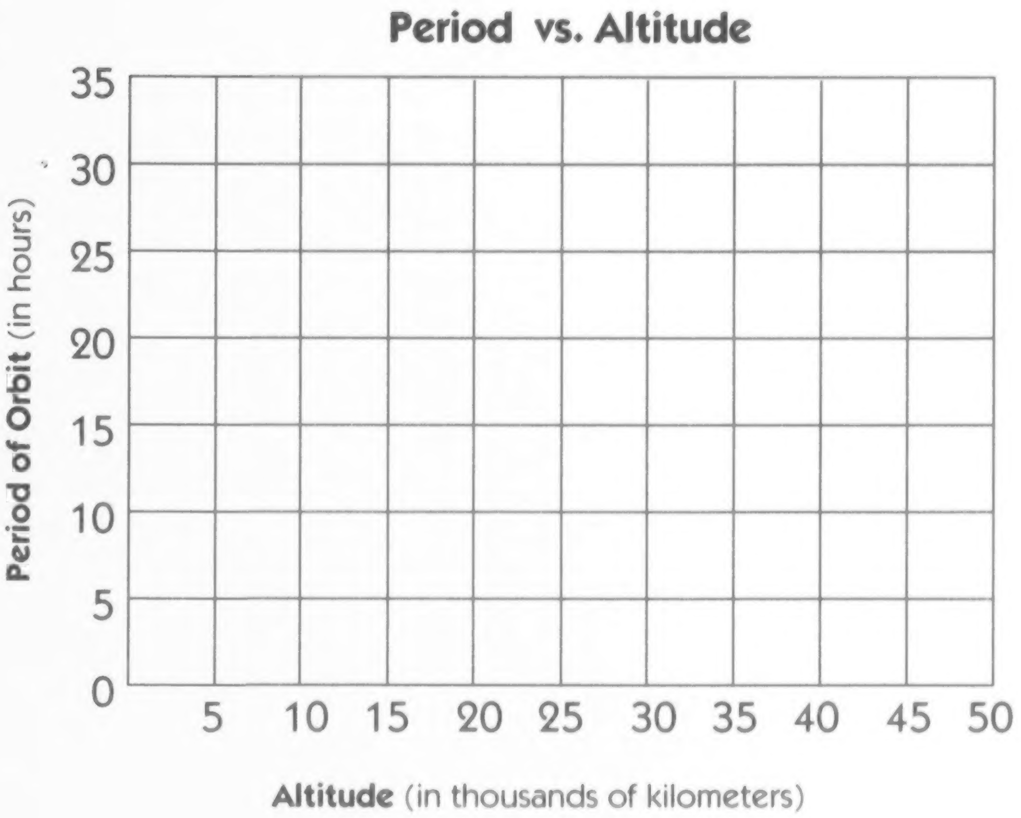
Weather satellites - These carry TV cameras that take pictures of the Earth from high above it. Equipment in a satellite translates the picture to a signal, sends it to a downlink antenna, and then changes it back to a picture. These satellites pass over different parts of the Earth with each orbit; they are not geosynchronous.

MASTER 2.3f

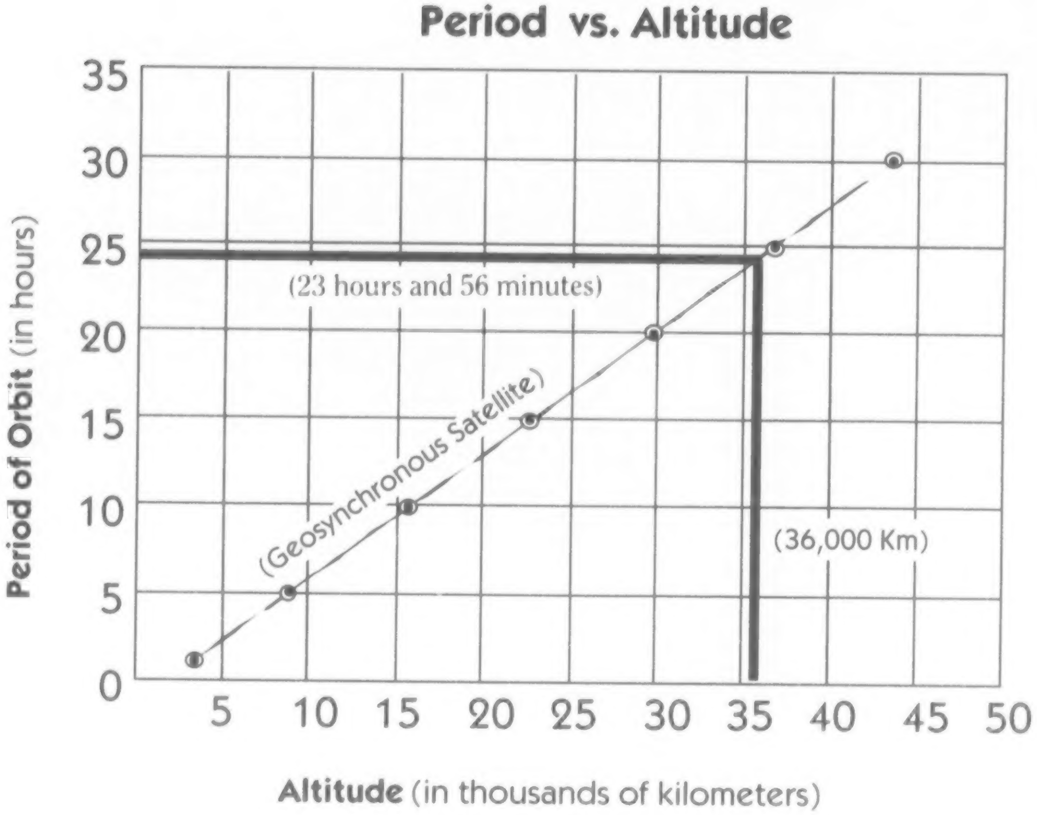
Geosynchronous Orbit


Earth's Axis
Equator
Spacecraft Antenna Coverage
Circular Equatorial Orbit
Earth's Rotation
Stationary Antenna Coverage
Altitude 36,000 km
(21,600 miles)
Speed 11,000 km/hr
(6,600 mph)
EDS

Revolution Times Worksheet



Back of Master 2.3g
Answer Key



Distance Chart

Selected Period of Revolution vs. Radius and Altitude

Period		Radius		Altitude*	
Hours	Sec	Km	Miles	Km	Miles
2	7,200	8,060	4,836	1,680	1,008
5	18,000	14,850	8,910	8,470	5,083
10	36,000	23,570	14,142	17,190	10,320
15	54,000	30,890	18,534	24,510	14,706
20	72,000	37,420	22,452	31,040	18,624
25	90,000	43,420	26,052	37,040	22,224
30	108,000	49,030	29,418	42,650	25,596

* Altitude = Radius of Orbit - Radius of Earth
Radius of Earth = 6,380 km (3,828 miles)

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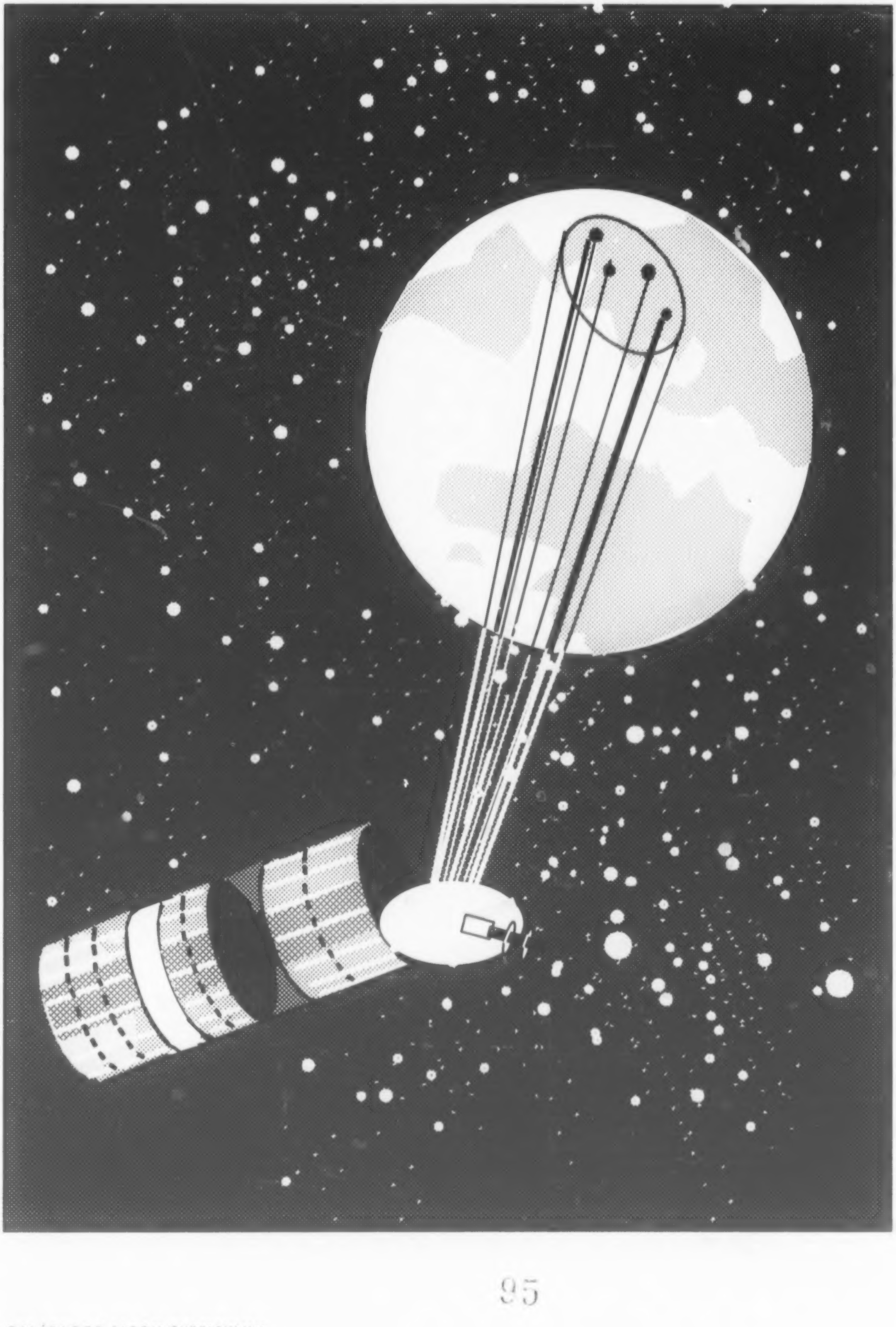
MASTER
2.3i

Satellite Footprints



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JASON TRANSMISSION: BRINGING IT ALL BACK HOME

2.4

ACTIVITY ONE

Energy Waves

Rationale

The images that JJ collects are transmitted to a satellite before being relayed to the downlink sites. Students need some knowledge of energy waves to understand how images are transmitted.

Objective

Students will demonstrate how an energy wave performs.

VOCABULARY

Dis•tur•bance - a change or motion that affects or disrupts the normal order of movement.

Tran•spon•der - a radio or radar receiver that automatically transmits electrical signals in response to specific activating signals.

Materials

- Overhead projector (*optional*)
- Transparency made from Master 2.3b, The Electromagnetic Spectrum (*optional*)
- 5-meter rope or clothesline
- Red ribbon

Procedure

A. Introduction

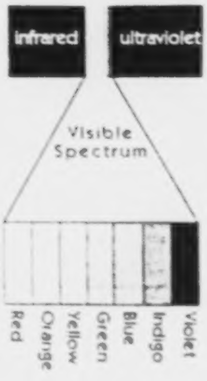
Explain: Electromagnetic energy moves through space in waves that can be measured. All energy waves travel at the speed of light, but waves differ in length and height. These differences are the codes that send the message.

One way JJ sends information is in the form of video images turned into bursts of laser energy. The equipment van on the ship receives this laser energy and turns it into invisible electronic energy waves that can be received by special equipment. This electronic energy is sent from the shipboard van to a satellite, which in turn sends it to the transmission station in Atlanta, Georgia. The signals are sent back to another satellite, and then to the downlink sites, where the receivers translate waves back into images.

The energy that creates waves comes from electrical charges or magnets. These electromagnetic waves can be measured. The range of all the wavelengths we can measure is known as the electromagnetic spectrum. Engineers measure the waves by the number of times a wave crest occurs per second. This is called the wave frequency.

TEACHER TAKE NOTE

If you did not do Activity One in Lesson 2.3, project Master 2.3b, The Electromagnetic Spectrum, and refer to it during this explanation.



In travelling to us (and through us), waves not only bring energy but also communicate meaning. Waves that are constant, as in the beam of a flashlight, cannot convey information. But if a beam is interrupted, or if its brightness can be made to change, then it can carry a message. This is how all wave-borne communications work.

B. Lesson Development

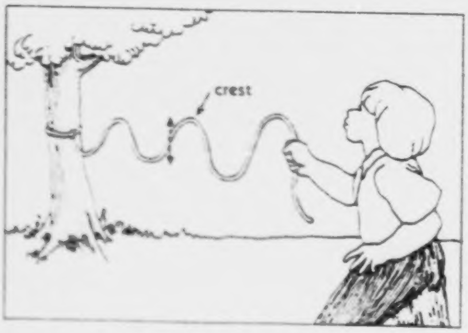
1. Take the class outside for this demonstration. Tie the clothesline or rope around a tree. Have a student stand at a distance from the tree that is slightly less than the length of the rope so some slack will remain when he or she grasps the rope.

2. Ask the student to give the free end of the rope a quick up and down jerk. Ask the other students to describe what they observe. Students should notice a wave moving along the rope.

TEACHER TAKE NOTE

Do *not* have a student hold the stable end. The activity calls for a powerful jerk on the rope that could potentially pull the rope out of either student's hands causing injury.

3. Next, tightly tie a piece of red ribbon on the rope about a third of the way from the free end. Now have the student give the rope another jerk. Point out that the ribbon goes up and down as the wave passes. Also note that each section of the rope moves vertically. It is the disturbance that goes forward, not the rope. (The red ribbon doesn't end up at the tree.) Explain that the disturbance or motion represents the energy that is transmitted from the uplink dish on the barge to the satellite. Put a loose ring (e.g. a shower curtain ring) on the line and snap the line. Does the ring travel?



4. Now snap the rope quickly several times. Notice how fast (or frequently) the waves move.

C. Conclusion

Explain that JJ's satellite signal is an assigned frequency that matches the sender/receiver or transponder channel on the satellite. The downlink dish at your expedition site is tuned to that signal. This is similar to tuning your radio.

ACTIVITY TWO

Transmitting the Blue-Footed Booby's Images

VOCABULARY

Tel•e•pres•ence - the sense of "being there" conveyed by video images of scientific exploration.

Rationale

The images seen on the control center monitors are created from coded signals passed in the form of energy waves between a satellite and receiving dishes at different locations in North America. This activity explains how these coded signals are translated into television images and dem on strates how rapid sequences of frames result in a moving picture.

Objective

Students will use prepared cards to simulate television image construction.

Materials

- One copy of Master 2.4a, Image Sequences (two pages, four sides)
- Transparency made from Master 2.4b, Television Line Scan Graphics
- 30 playing cards or 3 x 5 cards cut to size
- Glue stick

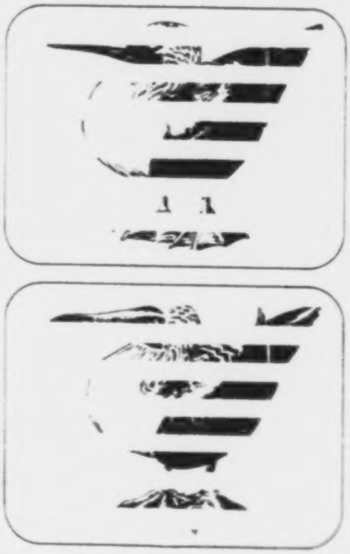
TEACHER TAKE NOTE

As a variation, copy the cards on regular paper, cut them out and staple them on the left hand side. The resulting flip-book can be fanned quickly and provides a sensation of motion. This can be a student activity if you make enough copies. Tell students this activity is a simulation of how cartoons and animated movies are made, and have them make their own movie.

Procedure

Teacher Preparation

Copy master 2.4a onto four pages. Cut the sequential pictures from Master 2.4a to match the size of the playing cards and glue each to one side of a card. (Notice that the position of the booby changes slightly with each image as the picture sequence progresses. The progress is small, but there are noticeable increments.) Number the backs of the cards sequentially as you glue each one so they can be reordered conveniently.



A. Introduction

Explain that JJ's images are transmitted as energy from the uplink on the ship to the satellite. An image is information in the form of a picture. To send information across space, energy must be delivered from one place to another.

Project the transparency of Master 2.4b, Television Line Scan Graphics. Explain that in the United States and Canada, television images are made up of 525 lines with 300 points along each line. An electronic beam scans the lines of the picture from top to bottom, left to right, line by line, point by point.

JJ's images also transmit color signals. Each of the 525 x 300 elements has a specific brightness and color quality. When all are recreated as a single image, they will form one frame. JJ sends 30 complete pictures (or frames) each second. The rapid sequences create full motion pictures. As a fish swims by, the movement of its fins on the display screen will be transmitted line by line, 30 full frames (pictures) per second, so students observe real movement.

B. Lesson Development

Have students take turns fanning the cards and viewing the appearance of motion. Point out that each card represents a frame that will be transmitted line by line, left to right. Remind students that JJ's imaging consists of 525 lines for every complete picture, similar to one picture card. Each card (frame) must be scanned line by line. Thirty of them are scanned and transmitted each second.

TEACHER TAKE NOTE

A single TV frame is actually composed of two sets of lines (fields), one set of even lines and one set of odd lines. When viewed at 30 frames per second, the two fields combine and appear as a single frame. Overlaying the frames creates the illusion of motion.

C. Conclusion

Discuss with students the relationship of the movements of the line images to the feeling of telepresence.

ACTIVITY THREE

TV Production

Rationale

Presenting the JASON Project expedition to the Galápagos Islands as a telepresence experience requires a team of producers, writers, directors, videotape editors, sound engineers, and video technicians. While the JASON scientists and technicians explore and conduct experiments, the television crew uses its production skills to bring their observations to students at the downlink sites.

Objectives

Students will:

List the tasks that go into broadcasting the JASON expedition.

Plan and produce their own simulation of a non-fiction television program.

Materials

- Television and VCR (for introduction and play back of pre-recorded tapes)
- Student copies of Master 2.4c, JASON Television Crew Responsibilities
- Desk and two chairs to serve as an anchor set
- Third chair for interview guest
- Posterboard or large paper and art materials for graphics
- Paper and pens or classroom computer for preparing script
- Large newsprint pad or more posterboard and markers for making cue cards
- VHS camcorder, or separate video camera and video cassette recorder (for students to record material they can play back during the live program)
- Blank videotape (at least one)
- Microphones for reporters (You can use the microphone on the camera, but sound quality is better with individual hand-held microphones.)
- Videocassette recorder or playback deck for the TV, unless the camcorder has playback possibilities
- Second VHS camcorder to record the final TV program (*optional*)

Procedure

Teacher Preparation

If possible, videotape a news segment to show in the classroom. If you have cable at home, you may want to tape "CNN Newsroom," a 15-minute daily news show designed for students and telecast at 3:45 am EST. (This is not a typo.) Check your local listings for the time in your area. If it is not

TEACHER TAKE NOTE

You may want to introduce this activity briefly now and return to it as a culminating project, just before your visit to the downlink site.

VOCABULARY

An•chors - the members of a television crew who stay in a fixed location and serve as hosts.

Pre-re•cord•ed tape (also known as a *playback tape* or *roll-in tape*) - the video recording of one segment of a program, ready to be incorporated into the program.

Re•mote - live coverage of a reporter at a distant (or remote) location.

Re•por•ter's pack•age - a taped segment in which a reporter narrates copy over pictures. He or she may or may not appear on camera and may or may not conduct an interview. (If the reporter does appear and addresses the camera, this is called a standup.)

Run•down - a production outline.

Script - the copy (text) for each story or item covered in a telecast.

Tel•e•promp•ter - a mechanical and electronic device that allows an anchor to read copy while looking directly into a camera lens; the high-tech equivalent of cue cards.

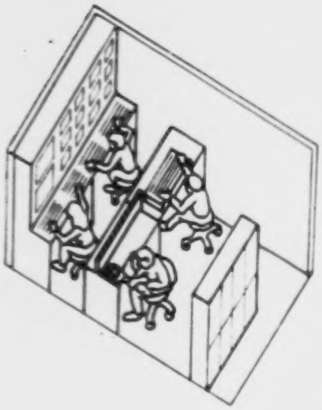
Toss - to yield the spotlight to another anchor or reporter.

TEACHER TAKE NOTE

If the program is going to incorporate pre-recorded segments, provide a separate videotape for each story. This will make the final program easier to assemble.

possible to show a video in class, assign students to watch a television newscast at home.

This activity could take as much as a week of classes or as little as one period. Decide how much time you can devote to it and whether the TV program your students produce will be entirely live, either with a camera or without (see younger students adaptation), or will include pre-recorded footage like most TV news programs and the JASON Project transmissions. Also decide if the finished program will be video taped for playback.



A. Introduction

Play portions of the show you videotaped for your class, or ask students to report on the news program they saw at home.

Discuss with your students what job is performed by each of the people they saw on camera: anchors, reporters, interviewed guests, and others. Ask students to list some jobs that are performed behind the scenes. (They may name the producer, the director, writers, field and studio camera operators, graphic artists, and others.)

Ask students to describe some of the things the producer, director, and other television personnel must do before broadcast time to prepare for a JASON Project program. What jobs must be done during the broadcasts? Direct the discussion to cover some of the basics outlined on Master 2.4c, JASON Television Crew Responsibilities, then distribute the copies and talk about any jobs that may have been neglected.

TEACHER TAKE NOTE

If your students are young, you may decide to take the role of producer or director. Most production decisions, however, should be made by consensus. If possible, choose a student who has had experience with video equipment to operate the camcorder.

Tell students that they are going to plan and produce their own television newscast. Like an actual newscast, the program will be made up of several segments, or stories. Ask for volunteers, or assign students to play the roles of producer, director, camera operator, and studio anchors.

B. Lesson Development

1. In a class discussion, decide what stories you will cover. If your taping will be done entirely in the classroom, subjects might include classroom science experiments and other activities, interviews with teachers or classroom visitors, or a survey of classmate opinions on a topic of general interest. Choose stories that can be illustrated with original drawings and art reproduced from textbooks or posters. If you can, send reporters and crew around the school or into the community. Possibilities include a video tour of the school building (including some areas students may not normally see and interviews with cooks, janitors, the principal, or the school nurse), a presentation at a school assembly, field day, a school picnic, or a ball game.

2. Devise a rundown with the students and write it on the chalkboard. Decide how many segments to include and how long each segment will play. The rundown lists the stories in the order they will take in the final newscast; this is an outline for the entire program.

Sample Program Rundown (two stories)

John (anchor 1) says hello and welcomes the audience.

Susan (anchor 2) says hello and gives an overview of the program.

Story 1: John tosses to Stephen (reporter 1) at reading area; Stephen interviews Anne about the book she's reading; Stephen tosses to Susan.

Story 2: Susan tosses to Peter (reporter 2) at teacher's desk; Peter interviews teacher; Peter tosses back to Susan.

Susan says good-bye; John says good-bye.

Roles and Responsibilities

Producer - with the teacher and other students, decides what topics the program will cover and keeps each segment to the appropriate length.

Director - arranges the set and decides on the best placement for anchors, reporters, interviewees, and camera crew.

Anchors - host the program, introducing stories, cueing reporters and recorded material; may conduct studio interviews.

Graphic artist(s) - prepare original art and/or find maps and other illustrations from books and posters.

Writers - write the scripts that anchors will read.

Cue card maker - works with writer to prepare final versions of scripts, makes large-print copy of each script to be used by student "teleprompter."

Teleprompter - holds cue cards off camera.

Reporters (at least one for each story) - set the scene for the story, fill in background, interview guests; may write their own scripts for reporter packages.

Studio camera operator - videotapes anchors and reporters during the live programming, zooms in to show artwork and pre-recorded tapes if appropriate.

Field camera operator (optional, only if pre-recorded sequences are to be used) - photographs live action sequences, in or out of the classroom, to be incorporated into the final program. Shoots only the amount of videotape that will be needed for each story, in the order in which pieces will be used during the newscast.

Playback operator (only if taped sequences are to be used) - inserts playback tapes at a cue from the director.

3. For each story, depending on its complexity, assign reporters, a graphic artist, and a writer or writers for the copy that anchors will read. If the program is going to incorporate pre-recorded segments, send the camera crew and the reporters to their locations while other students remain in the classroom to work on the graphics, the anchor script, and the set.

4. Spot reporters around the classroom. Have the director (and his/her assistants, if any) set up a TV studio, using a desk and two chairs facing the audience as an anchor position. If pre-recorded segments will be shown, place the TV set to one side of the anchors, also facing the audience, and position the playback operator with his/her equipment.

TEACHER TAKE NOTE

Video shot from the television screen will produce an unsteady image, known as a *roll*. Explain to students that a TV studio has equipment to prevent this from happening.

5. If class time allows, rehearse the program. If it will be taped, tape each individual segment separately. The director can tell the studio camera operator when to stop and start the camera. If there is no field camera, the camera operator can move to other sites in the classroom as often as necessary.

6. Assign the camera operator and the "teleprompter" to their positions. If the entire program is going to be live and in the classroom, begin taping at this point. Be sure that all on-camera participants face the camera, not the audience.

Depending on the content of the program, the anchors will either

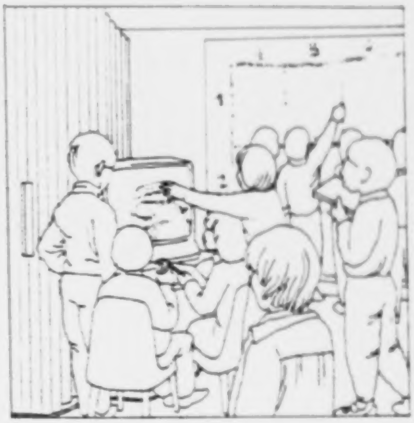
– set the stage and toss to various reporters, as in the rundown above.

– read an introduction and narrate pictures from the playback tape.

– introduce a pre-recorded interview.

– introduce a reporter's package.

– introduce a guest and conduct a live interview. Reporters can conduct live interviews from their locations.



C. Conclusion

If the program has been recorded, view it together and critique your finished product. In any case, discuss the complexity of a professional broadcast such as the network news or the JASON Project transmission. Ask: What production tools or techniques do these involve that are beyond the scope of a classroom exercise? (computer graphics; live remotes from faraway places, through satellite and microwave hookups; cameras at every reporter location; editing equipment to select the best footage and assemble it into precisely timed segments; intercoms so the producer and director can communicate without being heard on the air).

Tell students that part of the complexity involved in this year's JASON programming is that images will be recorded simultaneously from five camera sites. The shipboard director and technical director must decide which signals to broadcast based on what is happening at the moment at each camera site.

Discuss the differences between live and pre-produced programs. What advantage does live coverage have over taped material? How does live coverage of a football game, for example, differ from prepared highlights?

Ask students: What TV job would each of you most like to perform in the JASON Project? Assign interested students to choose one of the jobs involved in television production, learn more about its technical aspects through library research, and report back to the class.

Adaptations

For younger students

1. Plan a simple classroom skit, skipping the camcorder altogether. Instead of the video equipment in the materials list, use broomsticks or other materials for make-believe microphones and a still camera to stand in for the video camera. Do not use the master in the introduction. Have students discuss the basic production roles (producer, director, anchors, reporters, writers, graphic artists, and camera operators) and adopt them during the skit.

2. Instead of basing a program on events in their own classroom or school, have students simulate interviews at sites in the Galápagos Islands. These might include the Darwin Research Station, Academy Bay, or the underwater site off Punta Espiñosa. If an imaginary location is chosen, students to be interviewed could be assigned the roles of the participants in the JASON Project. (Master 1.1d in Unit 1, Lesson 1 provides profiles of participants.) Interviewees could also impersonate a 19th-century pirate stopping in the Galápagos for supplies, a present-day tourist, or a ranger at the Darwin Station.

3. If you have access to a camcorder, assign groups of students in turn to videotape an interview, event, or classroom activity. Instead of assembling these tapes into a finished program, have each group show its tape to the class. Follow with a discussion of how TV producers and reporters cover events in the field.

For older students

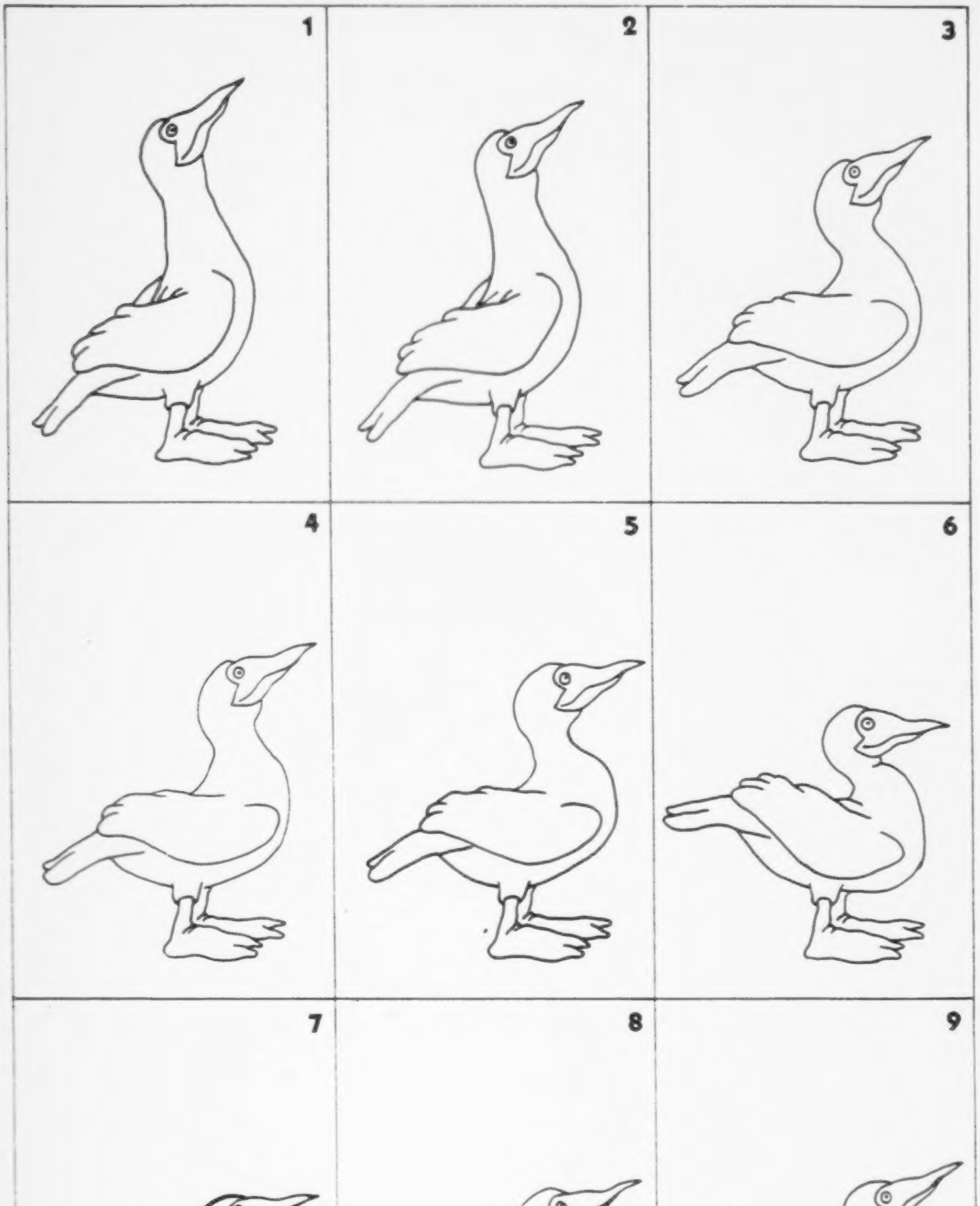
1. Increase the sophistication of the project to match available equipment and the students' technical proficiency. For example, high school students may be able to edit videotape, eliminating the need to shoot material in order and for precise lengths of time. Reporter narration tracks could also be recorded, and edited into the packages, rather than recorded in final form during the original shooting.

Reporter packages may be especially appropriate for older students. They could research and write stories as well as conduct interviews.

2. Discuss the different types of non-fiction TV formats: news programs; magazine programs, such as 60 Minutes or 20/20; and single-subject documentaries. Compare the kind and amount of pre-production that goes into each.

Image Sequences

MASTER
2.4a



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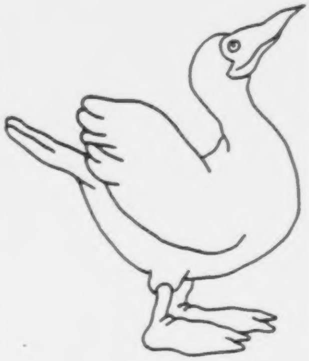

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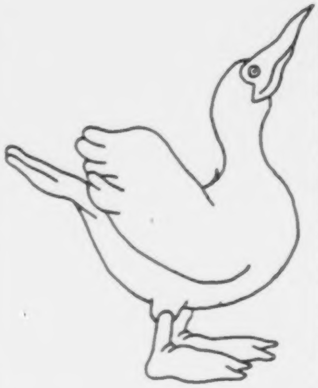

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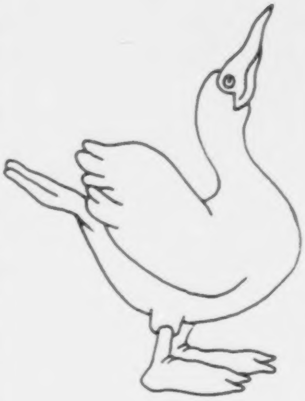

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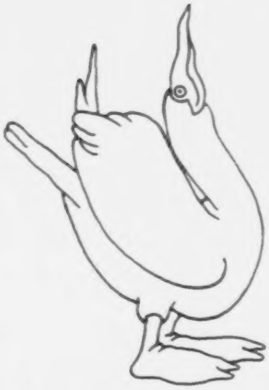

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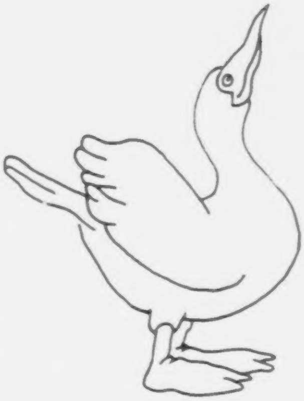

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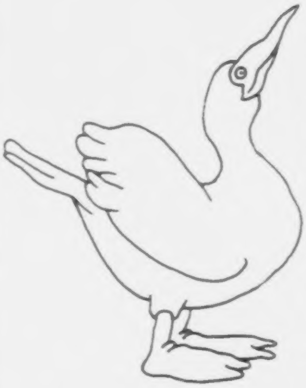

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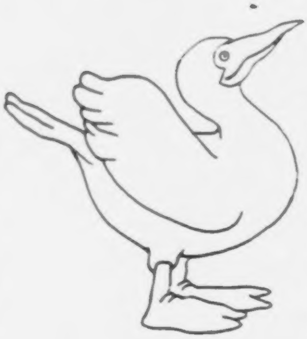

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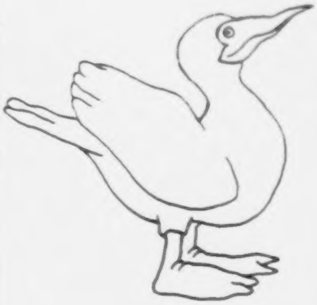

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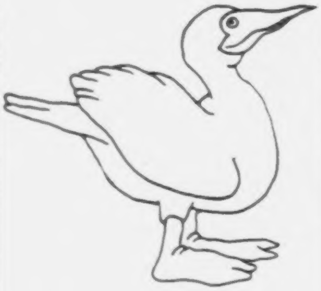

Image Sequences, Continued

MASTER
2.4a

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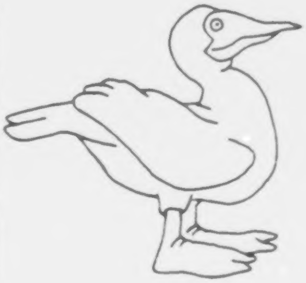

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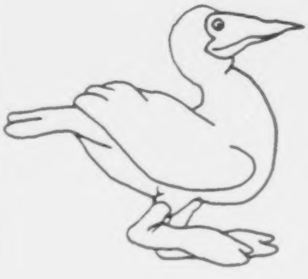

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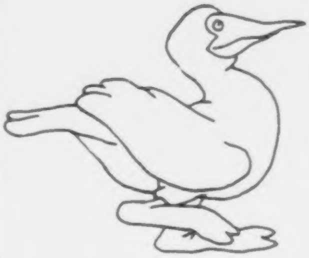

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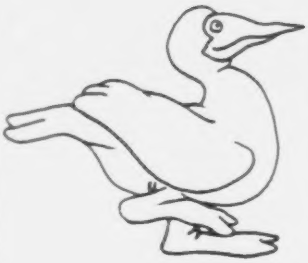

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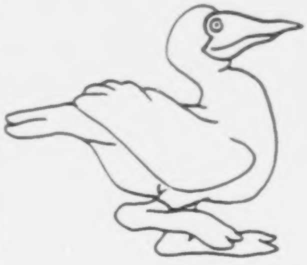

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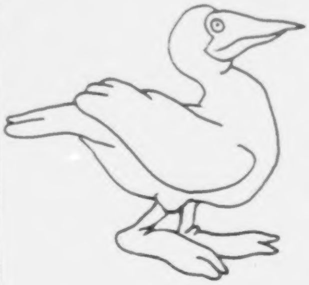

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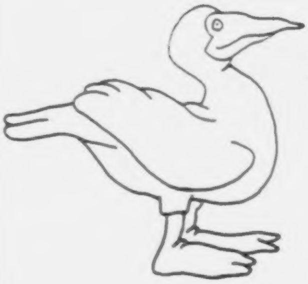

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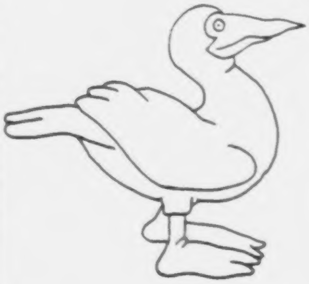

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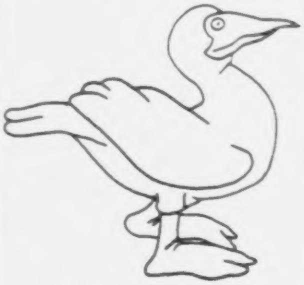

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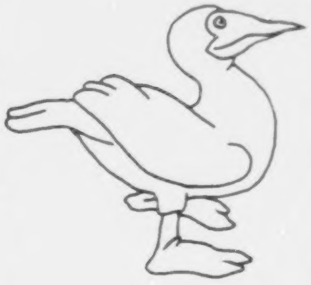

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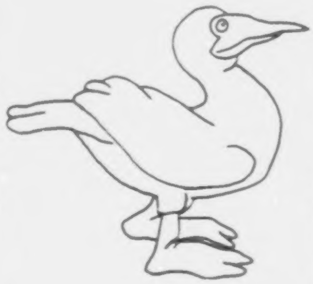

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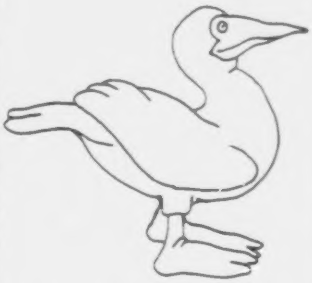

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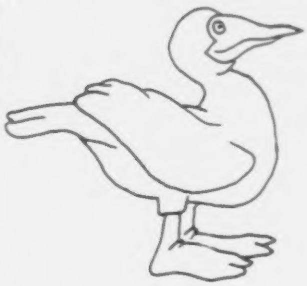

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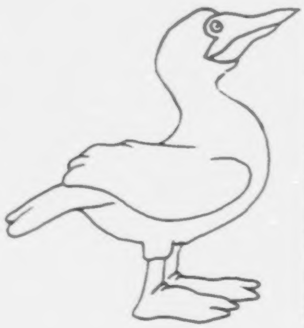

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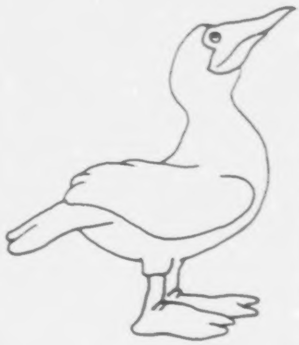

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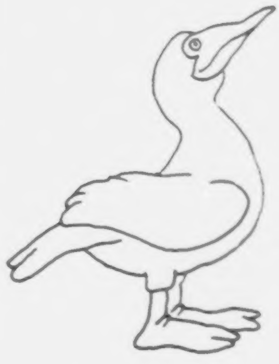

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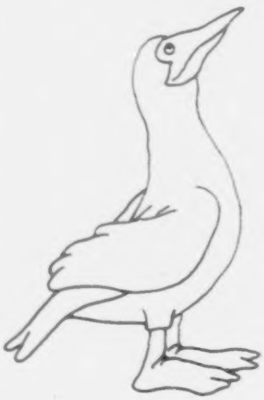

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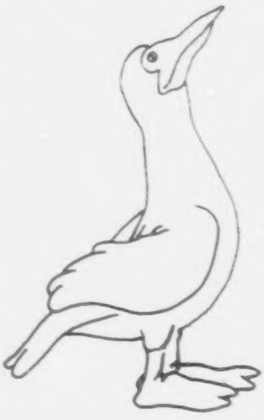
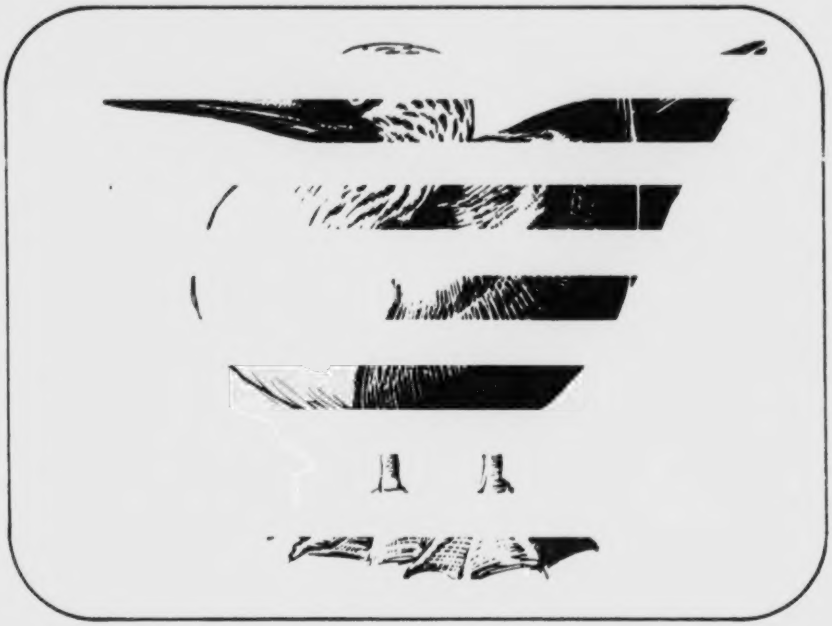
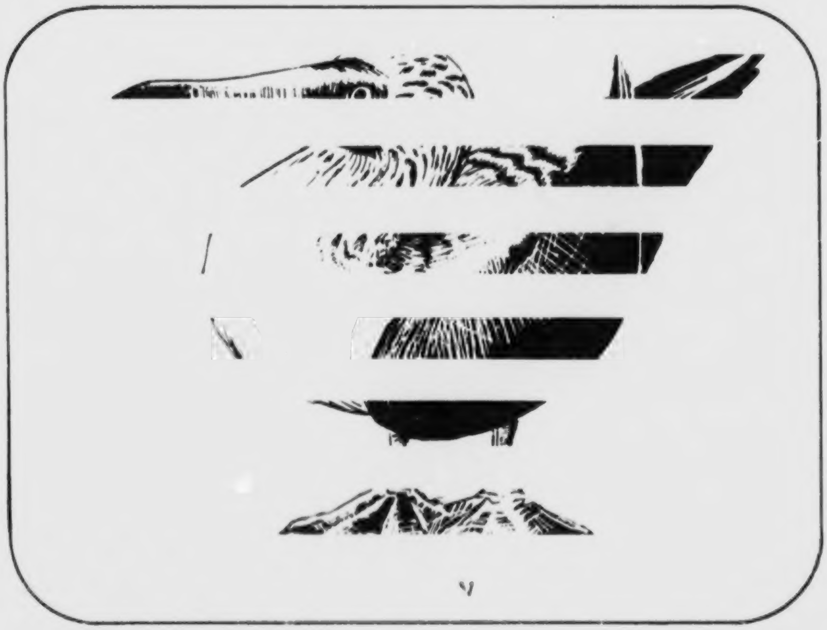


Television Line Scan Graphics

MASTER
2.4b





MASTER 2.4c

JASON Television Crew Responsibilities

Jobs Onboard the Ship

Shipboard producers coordinate the program. What topics should be covered in each program? What background reports, graphics, animation, and roll-in tapes should be used? What last-minute changes should be made to follow live events and to keep the program to its scheduled length?

Shipboard director supervises the technical crew. Where should the camera operators be? Which of their shots should be used and in what sequence? How should the lights be set up? When should tape machines roll? What special effects should be used?

Technical director operates equipment that switches the television pictures, operates an electronic effects generator, operates videotape machines.

Audio operators choose from dozens of possible audio sources, including microphones and prerecorded material.

Camera operators operate cameras in the control van and at the various remote sites. The camera operators maintain constant headset communication with the director.

Field audio technicians place microphones and monitor audio levels.

Teleprompter operators provide the electronic equivalent of cue cards, especially for the introduction and during the lead-ins to background reports.

Quality control engineer adjusts cameras and video signals.

Microwave engineers transmit video and audio signals from remote camera sites.

Satellite engineers coordinate the transmissions from the shipboard uplink.

Jobs on the Gateway JASON Production Van

(Additional production will be performed either at TBS studios in Atlanta, as in previous years, or in a production van located at the first U.S. downlink site, the so-called "gateway.")

Executive producer oversees technical and editorial decisions; coordinates interactive elements, such as remote flying and question and answer segments; maintains constant phone contact with shipboard personnel.

Director supervises technical team; maintains phone contact with shipboard director.

Still store operator plays back electronically-stored graphics.

Chyron operator types names, titles, locations, and other written information that is put on the screen.

Tape playback operator cues and operates videotape machines.

Audio personnel mix audio from the ship with other sources, such as telephone circuits to the museums.

Question and answer coordinator obtains name and age of questioner and passes on the nature of the questions to producers, who choose video and graphics to help answer the questions.

Master control engineers monitor quality of video and audio signals before they're uplinked to the museum sites.

Satellite engineers operate transmitters, uplinks, and downlinks, and manage transponders on telecommunications satellites.

THE GALÁPAGOS

JASON CURRICULUM

UNIT THREE

SCIENCE

BACKGROUND
Science

As a World Heritage Site, the Galápagos Archipelago is a living laboratory that belongs to all of us. The eight science lessons will prepare students to understand and appreciate the unique natural environment of the islands. It is important to emphasize to students that the JASON Project team will be collecting scientific data at each of five sites in the Galápagos. Studies will focus on counting populations and observing behavioral patterns of various animal species including the flightless cormorant; classifying deep water creatures using the baited "crittercam" to attract predators; and mapping subsurface geology and volcanology using side-scan sonar.

The lessons in Unit Three provide an interdisciplinary base for students' explorations, with the JASON Project team, on and around the Galápagos Islands. Geology and biology are the sciences most emphasized because the islands are volcanic, and many of their native species exist nowhere else on Earth. The study of weather also features prominently because of the significance of the El Niño events for all life in the Galápagos.

From the perspective of human history, the Galápagos Islands are ancient, but from a geological time perspective they are relative newcomers on the planet. Students will learn the difference between these two perspectives in the first lesson of the Science Unit. Then, in the second lesson, they will move from immensities of time to immensities of space, calculating the proportion of the Earth's surface that is covered with water. In the process, they will learn the importance of undersea exploration.

In the third lesson students will use gelatin desert to simulate a lava hot spot, illustrating the kind of volcanic activity that formed the Galápagos Islands. Then students will draw profile maps and observe how much of a volcanic island is underwater. Finally, they will model two basic types of volcanoes, strato and shield, and simulate the formation of a caldera.

The climate of the Galápagos is determined by the ocean currents that surround the islands. In the fourth lesson students will create currents in a body of water, demonstrate the process by which water level is equalized across the world's oceans, and color-code maps showing the dramatic effects of this leveling process on sea surface temperature (SST). Finally, they will consider the effects a rise in the SST would have on the life forms of the Galápagos.

The flora and fauna of the Galápagos are best known for the role they played in Darwin's development of the theory of natural selection. Two lessons in this unit deal with adaptation and natural selection. In the fifth lesson students will survey the vegetative zones of a typical island in the Galápagos Archipelago and the types of vegetation which grow in each zone. Then they will relate the diverse animals of the archipelago to their specific environments, and consider the adaptations that allow each to thrive.

The Natural Selection Challenge, in the sixth lesson, models the development of various bird species from a common ancestor. In that lesson students will soak tomato seeds in dilute acid, simulating an adaptation that allows the Galápagos tomato to reproduce. They will also assemble paper rat skeletons to test one way scientists reconstruct the history of a species.

In lesson seven students will assemble food webs to depict the trophic levels of marine species in the Galápagos. The remaining activities in this unit deal with two major threats to established feeding patterns of Galápagos organisms: introduced species and climate change. Students role-play to gain an understanding of the effects of non-native goats on the native bird populations. In lesson eight they observe the effects of sudden climate change in data recorded from the El Niño event of 1982-83.

Upon completion of the science lessons, students will have enough background to be active participants in the Galápagos expedition!

THE GALÁPAGOS ISLANDS IN GEOLOGICAL TIME

3.1

Rationale

Students have a difficult time comprehending how short the span of human history is in relation to Earth's geological history. This lesson sets the stage for Jason Jr.'s exploration and the study of the Galápagos Islands by providing a context in geological time.

Objective

Students will compare the time period of their own lives and that of human history to the age of the Earth and events in Earth history.

Materials

- Student copies of Master 3.1a, Twenty Centuries Worksheet
- Twelve 500-sheet reams (one case) of 8½" x 11" paper
- Master 3.1b, Selected Events in Human History
- Master 3.1c, Earth History Events
- Scissors

Procedure

Teacher Preparation

Obtain 12 reams of standard-size paper and stack them on a desk where they will be visible to all students. Unwrap only the top ream. On each of the lower reams, cut a strip 7- to 10-cm wide from the side of each wrapper so the paper shows through. The result should be a column of exposed paper edges 11 reams high. Stack the unwrapped twelfth ream neatly on top, and place a copy of the Twenty Centuries Worksheet on top of the stack.

Make a copy of Master 3.1c, Earth History Events, and cut it into strips along the dashed lines.

A. Introduction

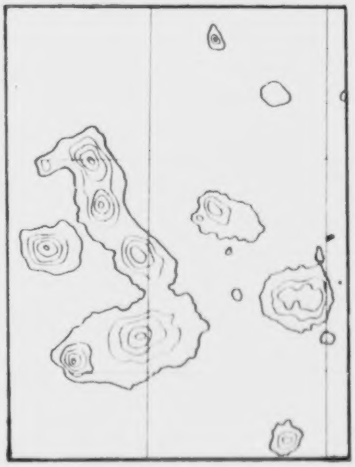
Ask the students to tell you what they mean when they say that something happened "a long time ago." (Answers will range from a few months to centuries and beyond.) Ask students if it was "a long time ago" that the Galápagos Islands started forming, dinosaurs became extinct, and our earliest human ancestors first appeared. Then ask them to guess the order in which these events occurred. Record their guesses without comment.

VOCABULARY

In•dex fos•sil - a fossil that, because its approximate date is known, allows scientists to determine the age of the rock in which it is imbedded.

Ra•di•o•met•ric da•ting - the process of using natural radioactivity to determine the age of rocks.

Stra•ta (s. *stratum*) - layers of rock or other material formed at different periods in geological time.



Emphasize that scientists seek proof of how long ago different events occurred by studying things which record the passage of long periods of time, such as the layers in rocks (*strata*) and *index fossils*. A large sequence of strata indicates a long time period of deposition. Index fossils represent species that existed only during specific time periods, so their presence is an index to the age of the rocks. Radiometric dating techniques can also reveal how long ago rocks were formed. The dating of events that occurred a long time ago and the sequence in which they occurred are among the puzzles scientists must solve. We are constantly adding to our knowledge of Earth history.

B. Lesson Development

1. Distribute copies of the Twenty Centuries Worksheet (Master 3.1a). Holding up the copy you placed on top of the paper stack, tell students that the stack is 12 reams high, and that every page in it stands for the same period of time. Explain that every dot on the sheet stands for one year. The first dot on the top line represents this year. Each dot after that one is a previous year. The entire sheet contains 2,000 dots. Ask the students to circle the dot representing the year in which they were born.

2. Distribute copies of Master 3.1b, Selected Events in Human History. With these sheets and their Twenty Centuries Worksheets in front of them, have students place the number of each event on Master 3.1b on or near the dot that represents its year.

3. Tell the class that geologic time calls for a different scale than historical time. Instruct students to change the name at the top of their Twenty Centuries Worksheet to read *Two Thousand Centuries Worksheet*. For the next activity, every dot represents 100 years.

4. Each sheet of paper in the 12-ream stack now represents 200,000 years. The farther down the stack the sheet is, the farther back in history the time it represents. Ask students to determine how far down in the stack a sheet representing one million years ago is located. (It will be five sheets down.)

5. Ask students how many dots there would be in a ream of 500 sheets of paper if each sheet had 2,000 dots. (1,000,000 dots) If each dot represents 100 years, how many years would a ream of sheets represent? (100 years x 1,000,000 dots per ream = 100,000,000 years.)

6. Distribute the strips of paper cut from Master 3.1c, having each student choose one.

7. Give students these directions:

- Look at your paper strip and decide if the event it names will fit within the span of years represented by the reams of paper (1.2 billion years).

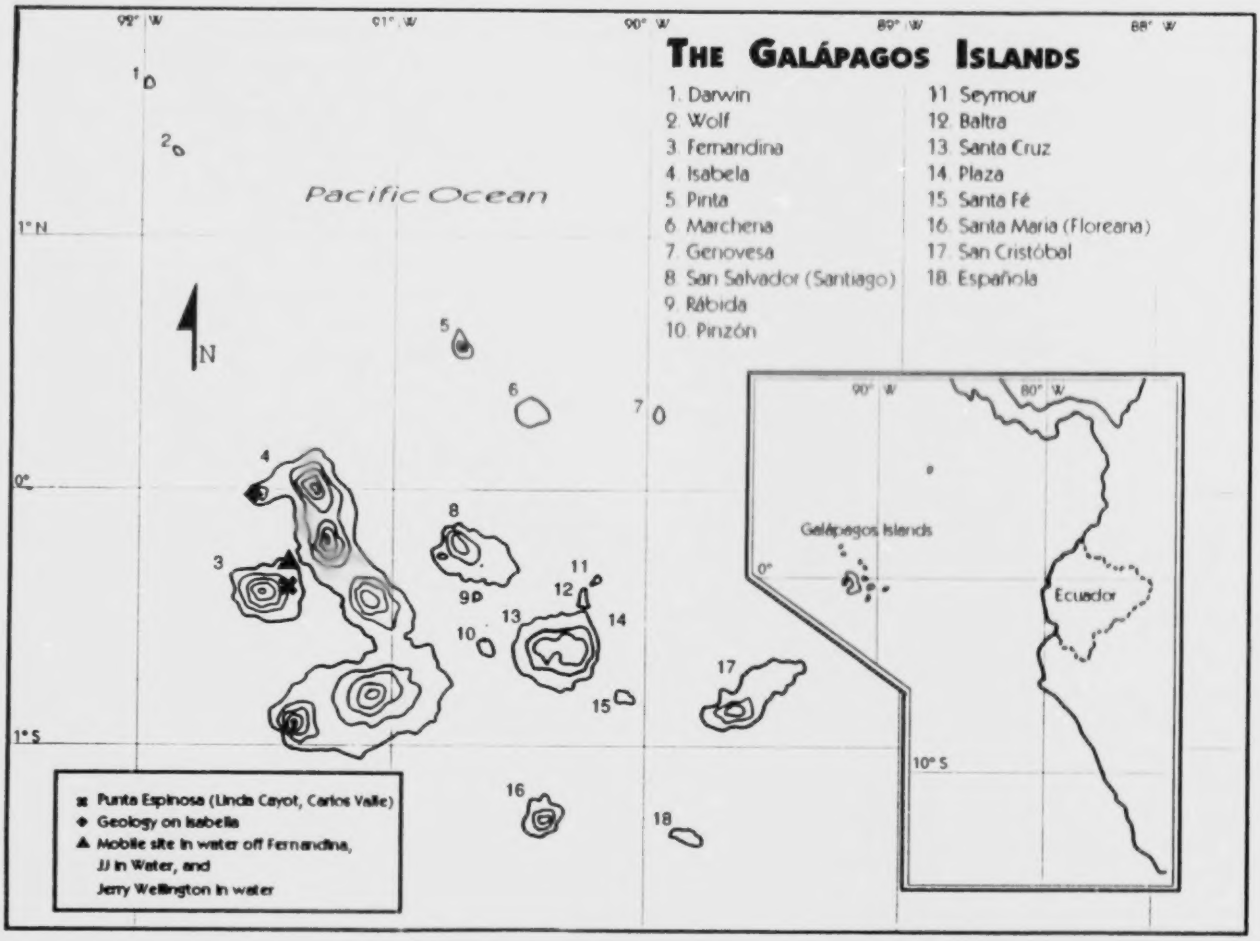
- If it does, calculate how far down in the paper stack to place your individual marker, then come forward to place it at the correct depth.

- If it does not, use the math we have already done to calculate how much more paper would be needed. Share your findings with the class.

8. Elicit ideas from the class on the age of the Earth. If no one knows, tell them that most scientists agree on a figure of about 4.6 billion years. Ask: How many reams of paper like the ones in the front of the classroom would it take to represent that many years? (46 reams)

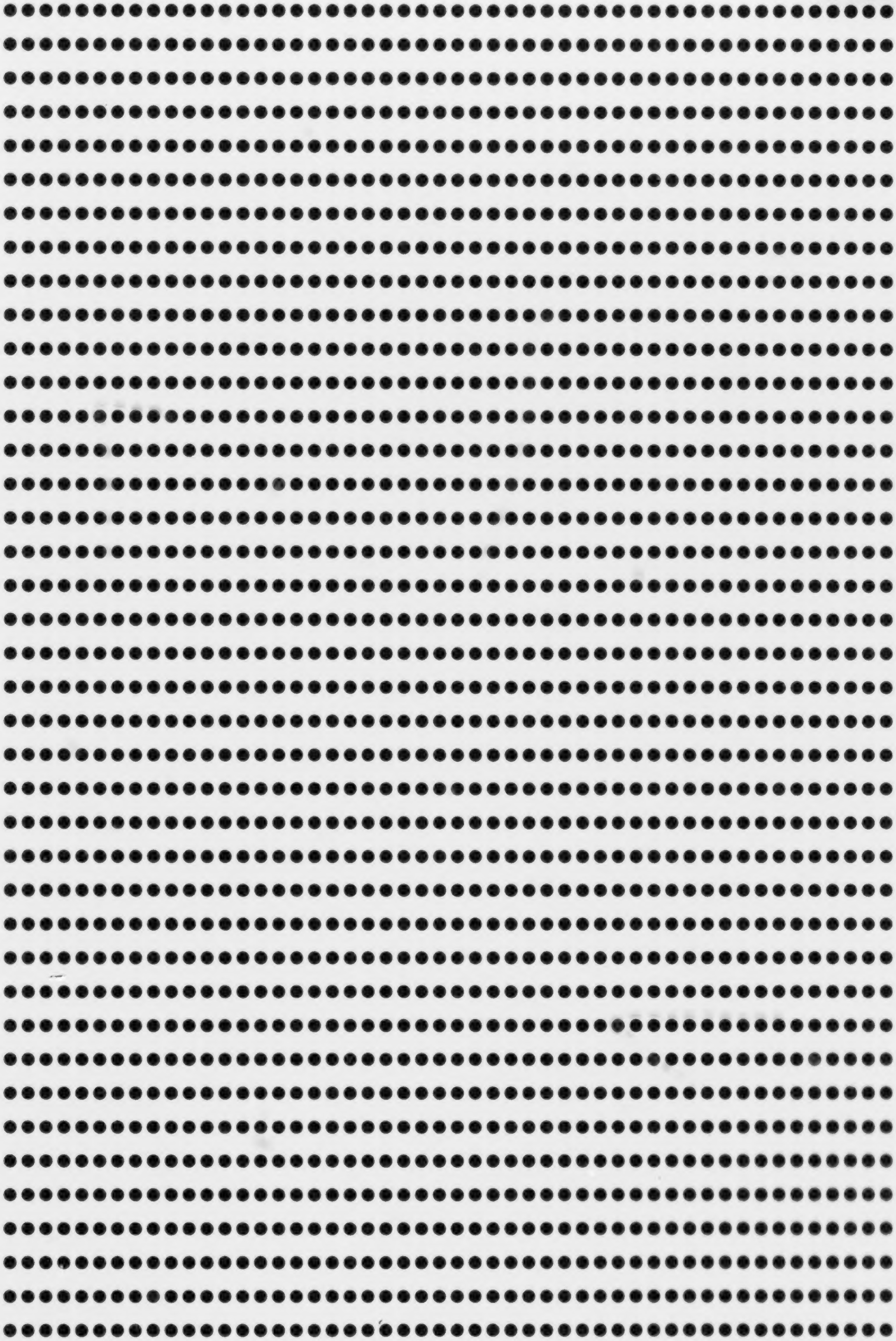
C. Conclusion

Ask the class: Now that you have an idea of the age of the Earth, would you describe the Galápagos Islands as young or old? (They are relatively young, ranging from less than a million years old to between three and five million years for the oldest islands.) Which occurred more recently, the extinction of the dinosaurs or the appearance of human beings? (The appearance of humans.) Compare these facts with the students' earlier guesses. Emphasize that terms like *young* and *old, long ago* and *recent* can have very different meanings in different contexts.


92° W
91° W
90° W
89° W
88° W
THE GALÁPAGOS ISLANDS
1. Darwin
2. Wolf
3. Fernandina
4. Isabela
5. Pinta
6. Marchena
7. Genovesa
8. San Salvador (Santiago)
9. Rábida
10. Pinzón
11. Seymour
12. Baltra
13. Santa Cruz
14. Plaza
15. Santa Fé
16. Santa Maria (Floreana)
17. San Cristóbal
18. Española
Pacific Ocean
1° N
0°
1° S
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
✖ Punta Espinosa (Linda Cayot, Carlos Valle)
◆ Geology on Isabela
▲ Mobile site in water off Fernandina, JJ in Water, and Jerry Wellington in water
90° W
80° W
Galápagos Islands
0°
Ecuador
10° S

Twenty Centuries Worksheet

MASTER
3.1a



MASTER
3.1b

Selected Events in Human History

1. ____— My great grandmother is born. (Estimate)

2. 1776 — U.S. Congress adopts the Declaration of Independence.

3. 1912 — Wright Brothers launch their first successful flight.

4. 1492 — Columbus reaches the Americas.

5. 1904 — Henry Ford markets the automobile.

6. 1989 — Robert Ballard launches the first JASON expedition.

7. 1835 — Darwin visits the Galápagos.

8. 1959 — The Galapagos is given National Park status and the Darwin Foundation is formed.

9. 1200 — The Inca Empire (later to include Ecuador) begins its rise.

10. 1564 — William Shakespeare is born.

MASTER
3.1c

Earth History Events

Earth formed - approximately 4.6 billion years ago

North and South America joined by the closing of the Isthmus of Panama - approximately 2,800,000 years ago

Last trilobites died out - approximately 225 million years ago

Earliest known hominoid (our early ancestor) fossils deposited - approximately 2 million years ago

Earliest known Galápagos rocks formed - approximately 4 million years ago

Earliest known animal fossils (jellyfish-like organisms) deposited - approximately 1.2 billion years ago

Earliest known fish fossils deposited - approximately 500 million years ago

Earliest known reptile fossils deposited - approximately 290 million years ago

Earliest known bird fossils deposited - approximately 160 million years ago

Earliest known mammal fossils deposited - approximately 200 million years ago

Earliest known flowering plant fossils deposited - approximately 135 million years ago

Earliest known trilobite fossils deposited - approximately 600 million years ago

Present-day Appalachian Mountains formed - approximately 250 million years ago

Rocky Mountains formed - approximately 70 million years ago

Mass extinction of dinosaurs and other forms of life occurred - approximately 65 million years ago

Breakup of Pangaea began - approximately 180 million years ago

Earliest known fossils of land animals deposited - approximately 390 million years ago

Last Ice Age ended - approximately 10,000 years ago

Oldest known rock on Earth formed in southwest Greenland - approximately 3.2 billion years ago

Alps and Himalayas begin forming as India joined Asian continent - approximately 30 million years ago

Formation of iron, copper, and nickel ores - 1 billion years ago

Much of continental land masses underwater - 330 million years ago

Active volcanoes in New England - 210 million years ago

Earliest microfossils formed in South African chert - 3.2 billion years ago

Algal stromatolites formed in Rhodesian limestones - 3 billion years ago

Sources for dates

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EXPLORING THE WORLD'S OCEANS

3.2

ACTIVITY ONE

How Much of the Earth is Covered with Water?

Rationale

Seventy-one percent, or more than two thirds, of the Earth's surface is covered with water. Students should be familiar with basic features of the underwater world, and how scientists learn about them.

Objective

Students will calculate the percentage of the Earth's total surface that is covered by water.

Materials

- Map or globe
- Student copies of Master 3.2a, World Map with Grid
- Pens or pencils and paper
- Calculator (*optional*)

Procedure

A. Introduction

Ask students to guess what percentage of the Earth's surface is covered by water. They are likely to be astonished by the answer: 71 percent, or 361 million square kilometers. All the kinds of formations we find on land, such as mountains, valleys, and plains, are also found beneath the sea. It's not surprising, then, that most of the Earth's underwater formations have not been seen or explored. Use a globe or a world wall map to point out the land and water areas. Also use the world map to identify the Galápagos Islands and place them in relation to the nearest continent and country (South America and Ecuador). Remind students that this year's JASON expedition will take place partly on land, partly in shallow water, and partly in deeper water.

B. Lesson Development

1. Distribute copies of Master 3.2a, World Map with Grid. Tell the students they will be roughly calculating the percentage of the Earth's surface that is water.

2. Give them the following instructions:

a. Count the number of squares that are mostly covered with water. Record this figure. Be sure to count the Great Lakes and other inland waters.

b. Count the number of squares that are mostly covered with land. Record this figure. Estimate how many squares all the islands would occupy and add that figure to the total for land.

Water squares = ________

Land squares = ________

Total squares = ________

c. Divide the number of water squares by the total number and multiply by 100. This will give an approximate percentage of water area.

C. Conclusion

Ask: If our planet is mostly water, why do we use the word *Earth* to refer to both dry land and the planet itself? (Because we are land creatures.) Why has it taken so long for us to begin to learn about the ocean floor? (Because we are not adapted to live underwater.) Why are we finally beginning to learn about the ocean? (Because scientists have applied new technologies to help them gather data.)

ACTIVITY TWO
How Deep is the Ocean?

Rationale

Sonar data makes it possible for the JASON Project team to position JJ and maintain contact with the ROV. Sonar technology is responsible for much of what we know about the world underwater.

VOCABULARY

Bath•y•met•ric – referring to the measurement of the depth of large bodies of water. A bathymetric map is one that shows how deep water is at various points.

So•nar – a system that locates submerged objects by means of reflected sound waves.

Objectives

Students will:

Describe sonar and how depths are calculated from a position on top of the water.

Calculate depths from data provided.

Materials

- Paper and pencil
- Calculator *(optional)*
- Master 3.2b, Sonar Activity

Procedure

Teacher Preparation

Copy the sonar table onto the board.

A. Introduction

Ask students how we can find the depth of the ocean when we cannot see the bottom. Some students may suggest weighted lines lowered over the side of a ship. Explain that sailors used to use such lines when entering a harbor or shallow water area. However, a rope long enough to reach the deep ocean floor would be too large to carry on board ship and would take too long to use.

Tell students that today's oceanographers use sonar (**So**und **Na**vigation **R**anging) instruments to generate a sound signal that is bounced or "echoed" off the sea floor and then recorded on board the ship. By carefully measuring the round-trip time of the sound waves and taking into account the variables of temperature and salinity, navigators can accurately measure the depth of the ocean. This method was developed during World War II for locating submarines.

B. Lesson Development

1. Explain that the speed of sound in water is 1,500 meters per second, four times faster than the speed of sound in air. This speed can vary slightly depending on factors such as temperature and salinity.

2. Do this example on the board so that students may then calculate the depth at a sounding site.

Example: Round trip time = 7 seconds

7 x 1,500 = 10,500

10,500 / 2 = 5,250 meters

3. Have students work the problems from the sonar table you wrote on the board. To find depth, they multiply the time by 1,500, then divide the answer by two since sound travels to the bottom and back up again to the surface.

4. Hand out Master 3.2b, Sonar Activity. Review student answers.

SONAR TABLE

Time X (seconds)	**Speed** (m/sec.)	divide by	**=Depth** (meters)
2.0 sec.	1500 m/s	2	m
1.5 sec.	1500 m/s	2	m
2.5 sec.	1500 m/s	2	m
3.0 sec.	1500 m/s	2	m
4.3 sec.	1500 m/s	2	m

C. Conclusion

Ask: How has modern technology helped sonar operators? (Computers can do many calculations rapidly and store vast amounts of data.) What experience have students had with sonar? (Maps are produced using sonar, and motion pictures sometimes depict it in use.) Why are accurate maps of the sea floor needed? (Navigating safely, locating new economic resources, and locating lost ships are a few answers to expect.)

Explain that since the development of modern mapping techniques, the sea floor can be mapped accurately. One of Dr. Ballard's aims in every JASON expedition is to provide data for more accurate bathymetric maps.

When oceanographers started constructing their maps, they discovered that the sea floor was not a flat, featureless plain. The next activity will give background information about some of the exciting discoveries that have been made.

ACTIVITY THREE
Discoveries on the Sea Floor

Rationale

The theory of plate tectonics explains the volcanic origin of the Galápagos Islands and many of the Earth's other geologic features.

VOCABULARY

Plate tec•ton•ics – the theory that the Earth's surface is broken into irregular pieces, or plates, which move in relation to each other.

Objectives

Students will:

Describe the Earth's internal structure.

Review basic concepts of plate tectonics.

Identify seafloor features associated with plate tectonics.

Materials

- Master 3.2c, Galápagos Geology, Teacher Background Reading
- Colored pencils or markers (*optional*)
- Student copies of Master 3.2d, Plate Tectonics, Volcanoes, and Earthquakes
- Overhead projector
- Transparency and student copies of Master 3.2e, Cross Section of the Earth
- Student copies of Master 3.2f, Earth Plate Boundaries and their Movement
- Scissors and tape
- Student copies of both sides of Master 3.2g, Earth Plate Puzzle Pieces

Procedure

Teacher Preparation

Read the background material on Master 3.2c before class and decide on the best way to present this information.

A. Introduction

Distribute copies of Master 3.2d, Plate Tectonics, Volcanoes, and Earthquakes. Review the basic concepts with students, relating them specifically to the JASON explorations.

TEACHER TAKE NOTE

The jigsaw puzzle may seem excessively simple to teenage students, but it is a good analogy for explaining the Earth's plates.

B. Lesson Development

1. Project the transparency and distribute copies of Master 3.2e, Cross Section of the Earth. Identify the various portions of the Earth's layers. If students wish to, they may color the inner core yellow, the outer core orange, the mantle red, the crust black or brown, and the island arc green.

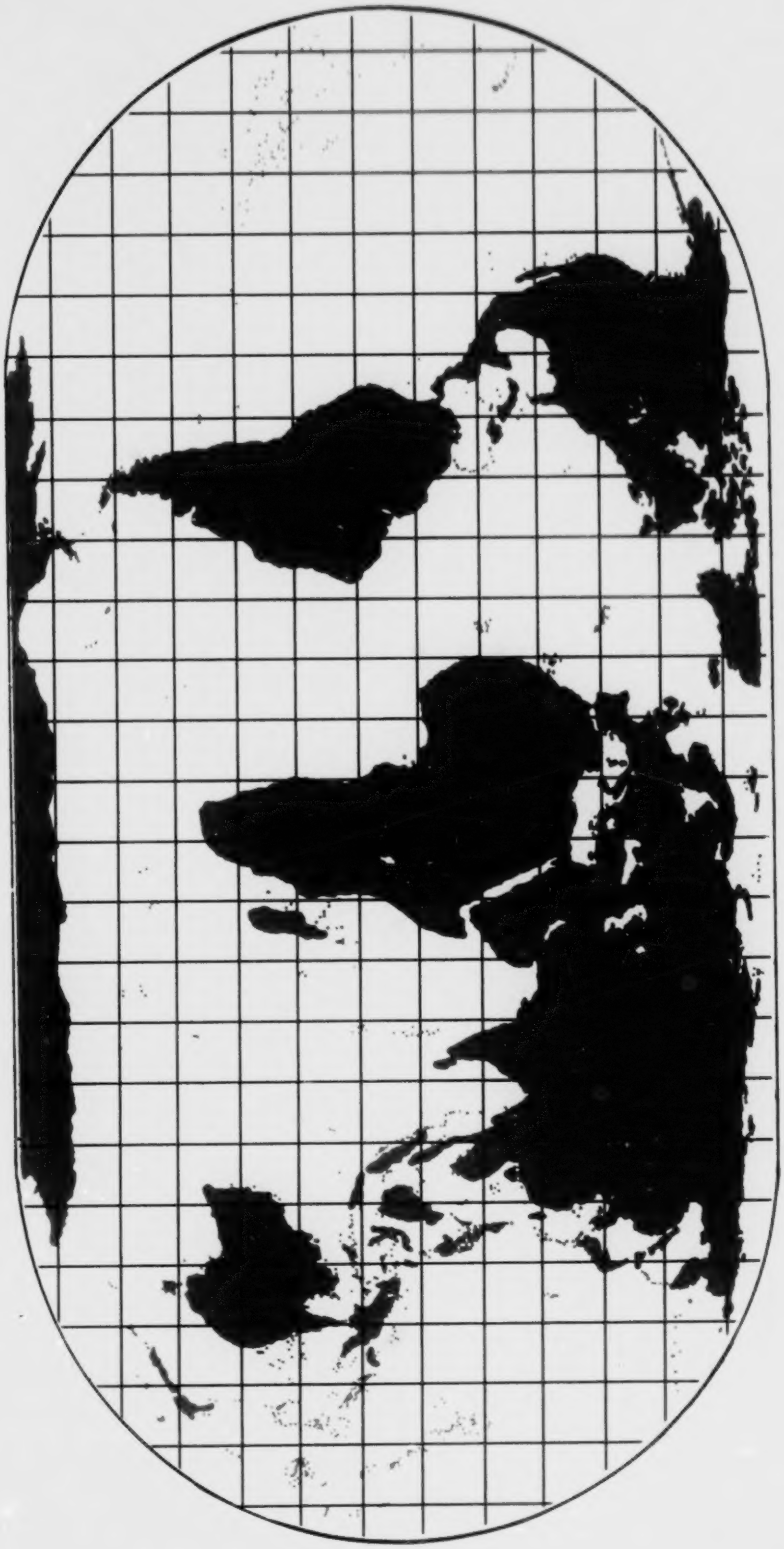
2. Hand out copies of Master 3.2f, Earth Plate Boundaries and their Movement, and Master 3.2g, Earth Plate Puzzle Pieces. Discuss and identify the major plates. Ask students to cut out the puzzle pieces and reconstruct the Earth's outline from them.

C. Conclusion

Have students compare their puzzles with Master 3.2f, Earth Plate Boundaries and their Movement. Describe the types of boundaries that the arrows suggest. Ask: What types of boundaries are in the Galápagos area? (Students may guess all three types, as the scale of this map does not allow for clear definition of the boundaries. If they look closely at the map, however, they will see that the Galápagos Islands are not next to the boundaries but some distance away. Galápagos volcanoes are formed when the Nazca plate rides over a hot spot in the mantle. There is more about hot spots in Lesson 3.3.)

World Map with Grid

MASTER
3.2a



Sonar Activity

MASTER
3.2b

You are the sonar operator for an oceanographic research ship. Your ship is searching for shipwrecks that have been reported in 1000 to 1200 meters of water. The captain asks you to give three locations to look for ships. This is the map that your sonar has generated. Use the formula (T)1500/2=D to calculate the depth of each location and write it in. Tell the captain which three grids to search.

	1	2	3	4
A	T=0.9 D=	T=1.0 D=	T=1.1 D=	T=1.2 D=
B	T=1.0 D=	T=1.1 D=	T=1.2 D=	T=1.2 D=
C	T=1.2 D=	T=1.3 D=	T=1.4 D=	T=1.5 D=
D	T=1.2 D=	T=1.3 D=	T=1.6 D=	T=1.7 D=

USE THIS SPACE FOR YOUR WORK.

SEARCH LOCATIONS
1.
2.
3.

Back of Master 3.2b
Sonar Activity Key

	1	2	3	4
A	T=0.9 D=675 m	T=1.0 D=750 m	T=1.1 D=825 m	T=1.2 D=900 m
B	T=1.0 D=750 m	T=1.1 D=825 m	T=1.2 D=900 m	T=1.2 D=900 m
C	T=1.2 D=900 m	T=1.3 D=975 m	T=1.4 D=**1050 m**	T=1.5 D=**1125 m**
D	T=1.2 D=900 m	T=1.3 D=975 m	T=1.6 D=**1200 m**	T=1.7 D=1275 m

TIME	DEPTH
0.9	675 m
1.0	750 m
1.1	825 m
1.2	900 m
1.3	975 m
1.4	1050 m
1.5	1125 m
1.6	1200 m
1.7	1275 m

SEARCH LOCATIONS

1. **C3**
2. **C4**
3. **D3**

Teacher Background Reading

Galápagos Geology

On the Earth's crust, the Galápagos Islands are located on the Nazca plate. On Master 3.2f, the map of the Earth's plate boundaries, it looks as if they were just below the smaller Cocos plate. In fact, however, the Galápagos spreading center at the plate boundary is 400 km (640 miles) away from the archipelago. The continental margin volcanoes of the Ecuadorian Andes are 1,000 km (600 miles) to the west, and the East Pacific Rise that forms the Gulf of California is the same distance to the east.

Both volcanic eruptions and earthquakes are common in the islands, but most of them are small. The active volcanism of the islands comes from something other than plate margin activity: hot spots rooted deep within the mantle. The hot spot responsible for the periodic eruptions on Fernandina supplies volcanic products to the plate as it moves over the hot spot to the northeast. The oldest of the Galápagos are probably only 3 to 5 million years old, and Fernandina, the youngest, which is still active, began to form about .7 million years ago.

Volcano Formation

Volcanic mountains like Fernandina are produced by repeated flows of lava (the name we give molten rock at the Earth's surface) from a vent or opening in the Earth's crust. The way the lava flows depends in large part on its mineral content, and so does the type of volcanic mountain produced.

Magma (or molten rock material underground) that has a relatively high silicon content is more viscous, or thicker than magma with a relatively low silicon content. This thick lava flows sluggishly, and cannot flow a great distance from the vent. A volcano with this kind of lava may erupt violently because of gases trapped inside as the magma approachs the surface. Its flows are often interspersed with dramatic eruptions that produce ash fall and cinders. A volcanic mountain that is built in this way, from layers of ash and viscous lava, is called a *composite cone* or *strato volcano*, and has the classic cone shape seen in pictures of Mt. Fuji and other steep-sided volcanoes like Mount Rainier, Mount St. Helens, and Mount Shasta. Its sides slope steeply to as much as 30 degrees. A strato volcano often has a funnel-shaped vent area at its summit called an *explosion crater* or *pit crater*.

A magma that has a relatively low silicon content is less viscous and releases its gases more easily as it approaches the surface. Thus it is less likely to be explosive, although groundwater mixing with the magma can produce an explosion. This type of lava is called *basaltic*, after the rock it commonly forms. In the course of successive eruptions, these thin flows will spread out to build a volcano with gentle slopes of six to twelve degrees. It is called a shield volcano because its cross section resembles the shape of a warrior's shield. A *shield volcano* will often have a steep-walled, flat-floored depression several kilometers in diameter at its summit. These depressions are called *calderas*, and are formed when the summit collapses because successive eruptions have drained the magma chamber below the surface.

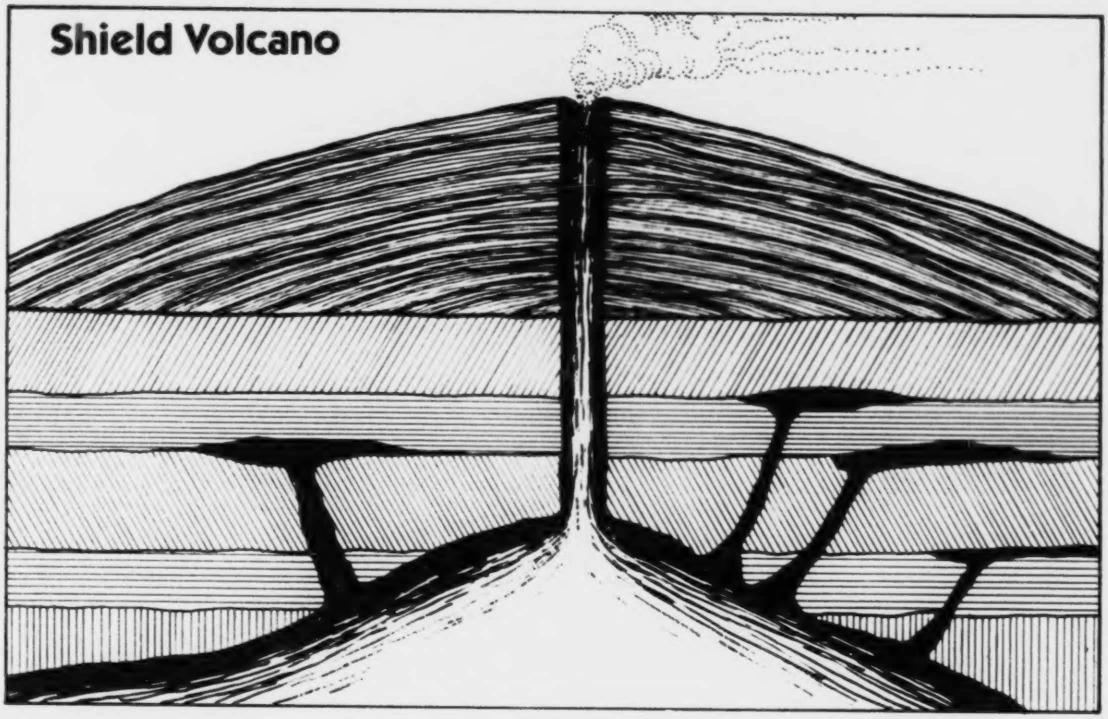
Shield volcanoes are typical of eruptions away from plate boundaries. They are less gassy, less explosive, and transport less fragmental material. There are cinder cone volcanoes in the Galápagos, however. Some of them, within summit calderas like the one on Fernandina, result from the explosive interaction of hot rocks and cold water.

Galápagos shield volcanoes are steeper than Hawaiian shield volcanoes. The flows are thicker, partly because they're loaded with crystals, and circumferential vents (vents around the summit crater) are more common. Sea floor volcanoes in the Pacific, just beginning to be studied, are mostly of the shield type.

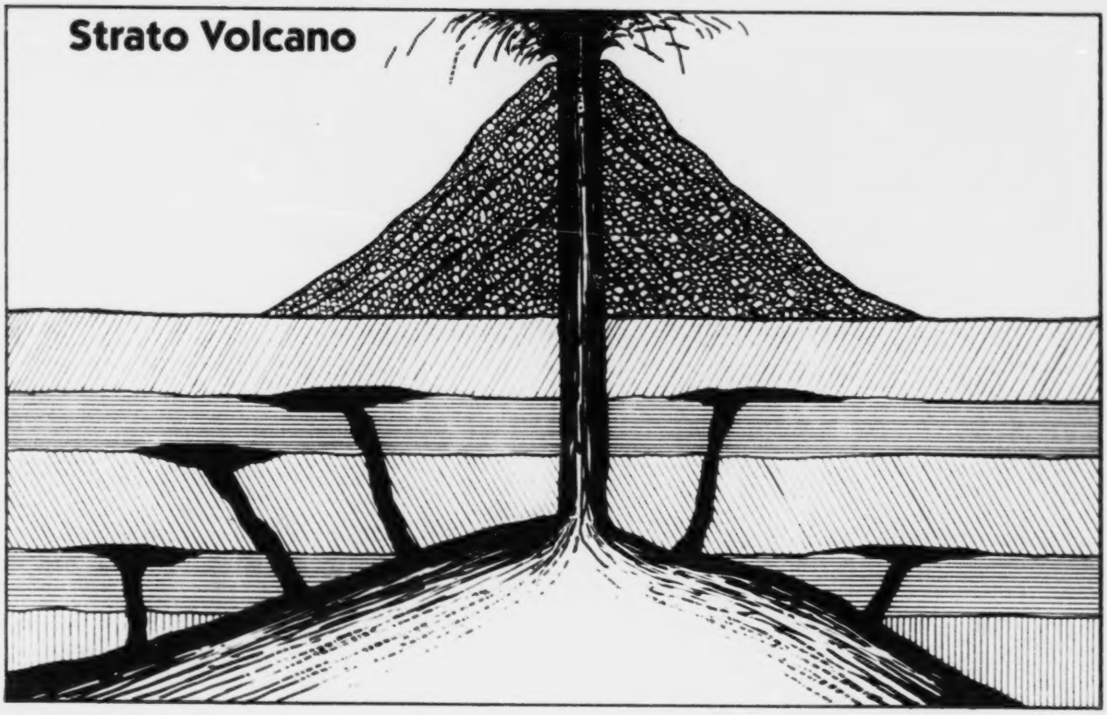
Types of Lava Flow

Because they are relatively fluid, lava flows from a basaltic vent can travel a great distance from the vent. When the flow leaves the vent area it is still hot (1200° C) and flows easily. As the surface cools it forms a skin that is dragged along by the molten material underneath, wrinkling its still plastic surface. This forms a lava flow with a relatively smooth wrinkled texture. Since the wrinkles often look like coils of rope, this type of flow is sometimes called ropy lava. Geologists call it *pahoehoe*, pronounced *pa hoy hoy*. As the flow cools it gets thicker and starts to crystallize, forming blocks of rocks that are broken up by moving lava flow. This type of flow is called clinker lava, or *aa*, pronounced *ah-ah*. (Aa is one reason that vegetation is sparse in the islands, except for the misty highland regions. Rainfall doesn't stay; it enters cracks in the lava flows.)

Because they transport large volumes of lava long distances with very little heat loss, *lava tubes* are recognized as important elements in the growth of large, broad, basaltic shield volcanoes. A lava flow will cool, crystalize, and form a crust insulating the flow and keeping the interior molten. As gravity pulls the lava downhill, the molten material flows from under the crust and in turn crusts over, extending the flow. New lava from the vent will flow under the crust to replace lava that drains out of the lower end. When the eruption ceases, the molten interior drains out the lower end, leaving a lava tube cave. Lava tubes are commonly about 5 meters (about 15 feet) in diameter and hundreds of meters long. These tunnels or caves make an ideal refuge for animals, and, when enough time has elapsed, a convenient hunting ground for fossils.



Shield Volcano



Strato Volcano

Plate Tectonics, Volcanoes, and Earthquakes

To understand why volcanoes and earthquakes occur we need to understand two basic concepts about the makeup of our Earth: that the globe we live on is composed of layers, and that its surface is broken into irregular pieces called *plates*. Much has been learned about the interior of the Earth through indirect observations, such as the way earthquake waves behave as they travel through the Earth's layers.

The Layers of the Earth

The simplest way of describing the Earth's layers is to compare the globe to a hard boiled egg. It has a *crust* something like the shell, a middle layer, or *mantle*, something like the white, and a *core* that is something like the yolk. The crust and the upper portion of the mantle are often referred to together as the *lithosphere*. Earth scientists further divide the core into the *inner core* and the *outer core*. Because of the tremendous pressures, friction, radioactive decay, and other sources of heat the interior of the Earth is very warm. Evidence collected from mines and deep wells shows that the average increase in temperature is about 1°C per 40 meters of depth. If this increase continued to the center its temperature would be over 150,000°C. Other evidence points to a temperature of about 5,000°C for the innermost core.

Crust, Lithosphere, and Asthenosphere

The Earth's solid outer layer, the crust, varies in thickness from about 30 km to 70 km on the continents to only about 6 km on the ocean floors. Even at its thickest point, it is not nearly as thick in relation to the whole bulk of the Earth as the shell of an egg is to the egg. Comparing 70 km, the greatest thickness of the crust, to 6,370 km, the radius of the Earth, makes this apparent.

The oldest rocks of the crust have been dated by radioactive decay at a little more than three billion years old. Earth scientists do not know when the lithosphere began to harden, but they assume that it broke into plates during the hardening process.

The lithosphere, including the crust and the solidified outer portion of the upper mantle, reaches to an average depth of about 100 km. It is deepest under the relatively stable continents and shallowest at the mid-ocean ridges and where active volcanoes are located. Directly below the lithosphere is a region with a plastic, semi-solid consistency, called the *asthenosphere*, which reaches to about 200 km below the surface.

Mantle

The mantle continues to a depth of 2,855 km. Earthquake waves indicate that this is a region of rock that behaves as a plastic, that is, it will bend and flow in response to pressure. Temperature and pressure continue to rise with depth until the core is reached.

Core

The liquid outer core, which might be compared to the outer two thirds of an egg's yolk, reaches from 2,855 km to a depth of about 5,155 km. The solid, metallic inner core goes the rest of the way to the center of the Earth. Both are thought to be composed primarily of iron and nickel.

The Earth's Plates

Most earthquakes and volcanoes are caused by large-scale movements of the Earth's plates, and occur at the boundaries between the plates. Earth scientists recognize seven to twelve major plates and a number of smaller ones. The plates take their names from continents (the North American plate); from oceans (the Pacific plate); and from geographic areas (the Arabian plate).

The plates are in very slow but constant motion, so that seen from above, Earth's surface might look like a slowly moving spherical jigsaw puzzle. The plates move at rates of 5 to 15 cm, or several inches, in a year: about as fast as our fingernails grow. On a human scale, this is a rate of movement that only the most sophisticated instruments can detect. But on the scale of geological time, it's a dizzying speed. Those three-billion-year-old rocks could have traveled all the way around the Earth eleven times, at this rate.

The result of this slow steady motion is the opening and closing of ocean basins. At the present time the Atlantic Ocean is opening at the expense of the Pacific Ocean, which is closing as the North American continent slowly moves westward. Over the past several million years the Mediterranean Basin has opened and closed as the African and European plates move toward each other. It is this motion that causes numerous earthquakes and related volcanoes.

Three Kinds of Plate Movements

The movement of the plates is generally one of three kinds: spreading, colliding, or sliding. When plates are spreading, or separating from each other, Earth scientists call their movement *divergent*. When they are colliding, or pushing each other, Earth scientists call the movement *convergent*. Movement in which plates slide past each other is called *lateral* plate movement. Earthquakes can accompany each of the three types of movement, but the most forceful quakes result from convergent and lateral movements. Volcanoes normally accompany divergent and convergent types of movement.

Continental Drift: 1910 to 1960

The theory of plate tectonics originated early in this century, although it did not gain general acceptance until the late 1960s. The German meteorologist, geophysicist, and explorer Alfred L. Wegener is now given credit for the first step in understanding the movement of the lithosphere. In the period 1910-1912, he formulated the theory called continental drift, and collected evidence from the rocks, fossils, and climate of various continents to show that they had once been joined together. Wegener had little data on the oceanic crust, and thought that the continents merely moved through that crust.

Plate Tectonics: 1960 to the Present

In the early 1960s, oceanographers Fred Vine and Drummond Matthews, using magnetic data from the sea floor, showed that the ocean floor was spreading apart at the mid-ocean ridges. They dubbed the process *sea floor spreading*. As study continued it was soon realized that the continents were also moving. By 1968 a new explanation for the dynamics of the Earth's surface had been devised. We call it plate tectonics.

Convection Currents

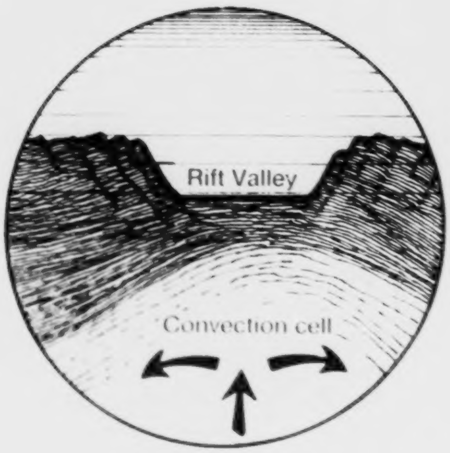
The force that drives the plates, however, is still something of a mystery. Wegener thought that centrifugal force, caused by the rotation of the Earth, was the cause of continental drift. The weight of modern scientific opinion favors convection currents, systems of heat exchange that take place in the mantle as it is heated by the core. The mantle's plastic-like material rises as the temperature rises and sinks when the temperature drops. You can see this kind of movement if you boil water in a clear glass pot. As the water is heated on the bottom, it becomes less dense and rises, while relatively cooler water from the top sinks, creating convection currents.

This convective movement acts as a drag on the underside of the lithospheric plates, causing them to separate where mantle material is rising and collide where it sinks. As the plates are dragged along over the mantle, like potato chips riding on honey, the leading edges of some plates are destroyed, while others pick up new material. Sometimes the edge of one plate slides under another, in the process we call *subduction*.

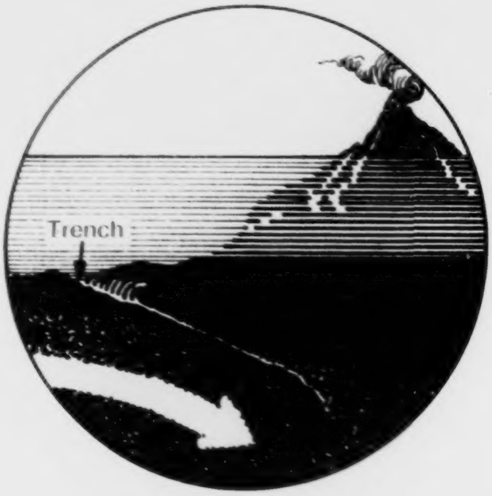
As a subducting plate sinks, friction from the downward-moving plate rubbing past the other rocks causes earthquakes deep within the crust. Eventually, because of the high temperature of the mantle and the extra heat generated by friction, the rock begins to melt. As the molten plate material becomes hotter, it becomes less dense and rises through the crust, forming magma chambers and volcanoes.

A Natural Cycle

A study of plate tectonics is essential to understanding the geological events that have built the Galápagos Islands. Earthquakes and volcanoes result from the same global processes occurring in the great sweep of geological time.

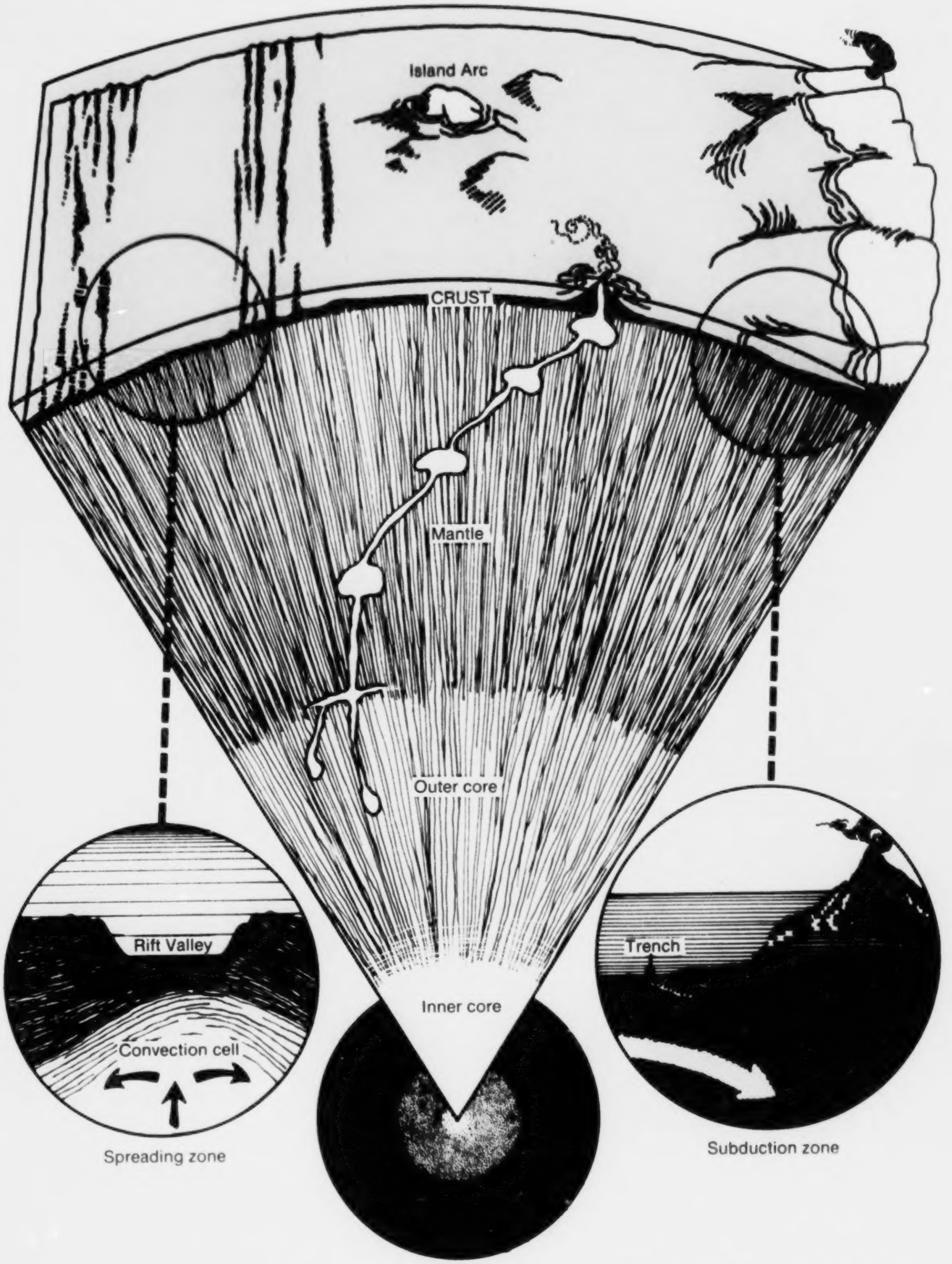


Spreading zone



Subduction zone

Cross Section of the Earth


Island Arc
CRUST
Mantle
Outer core
Rift Valley
Convection cell
Spreading zone
Inner core
Trench
Subduction zone

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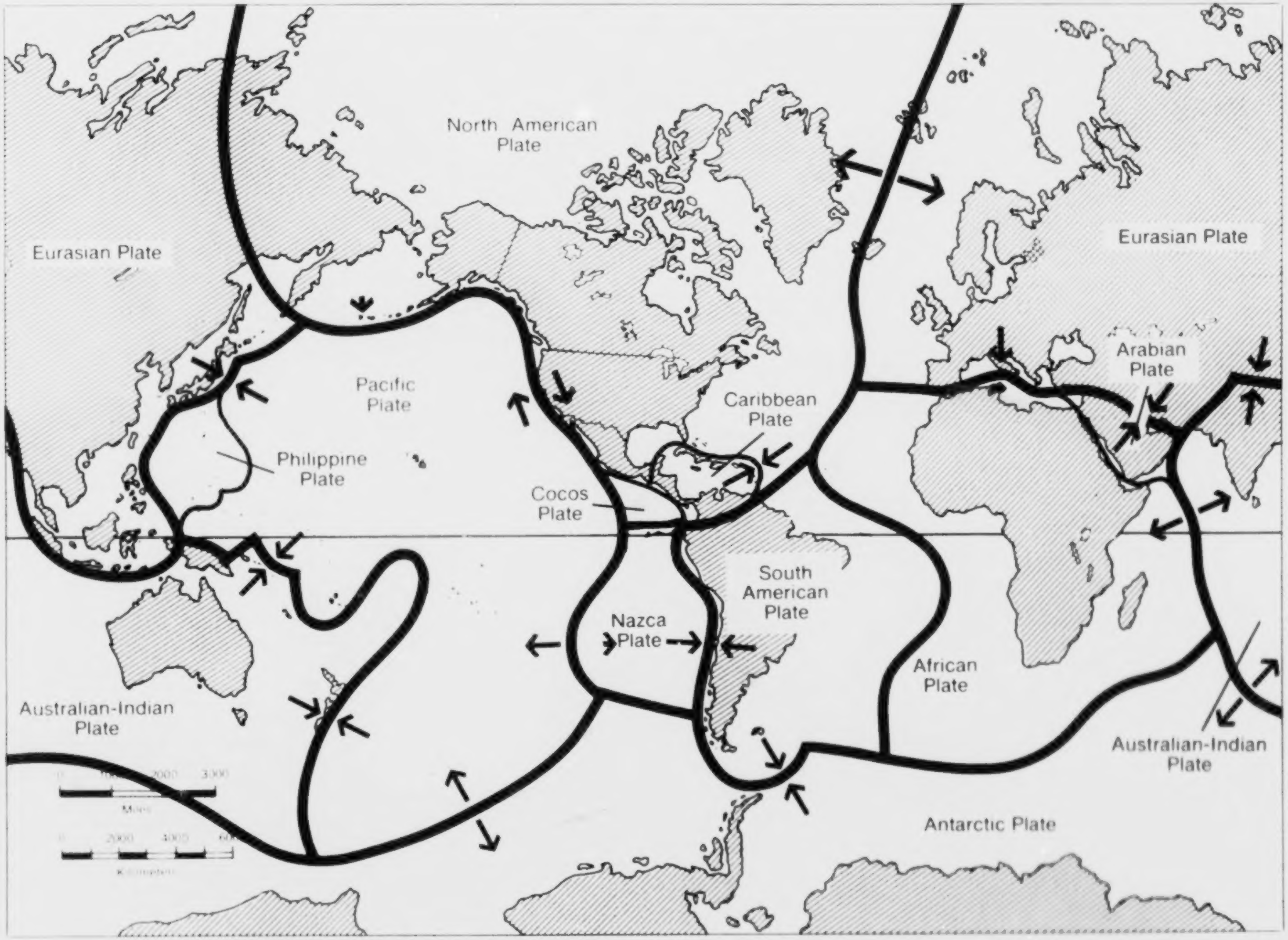
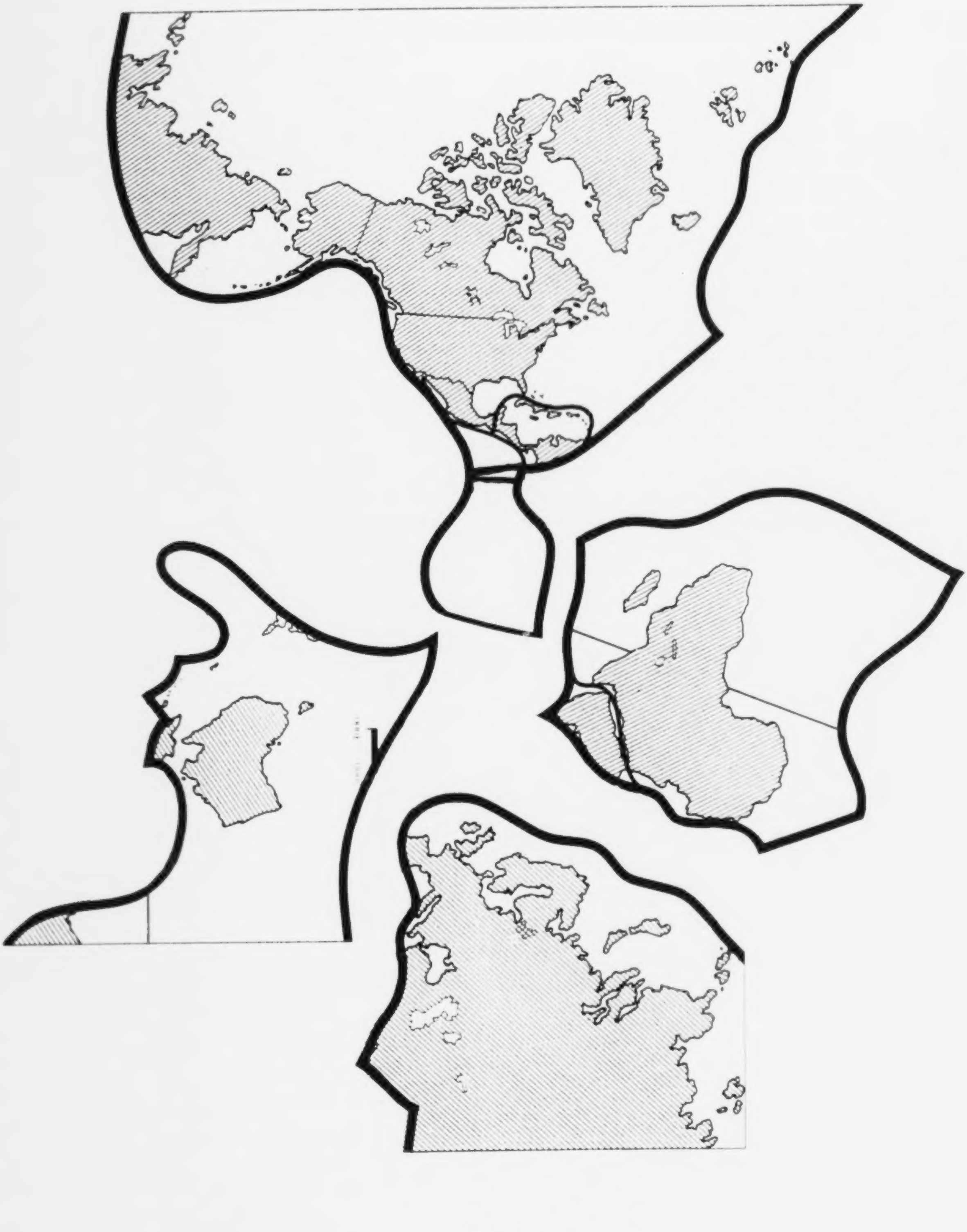
MASTER 3.2f

Earth Plate Boundaries and their Movement

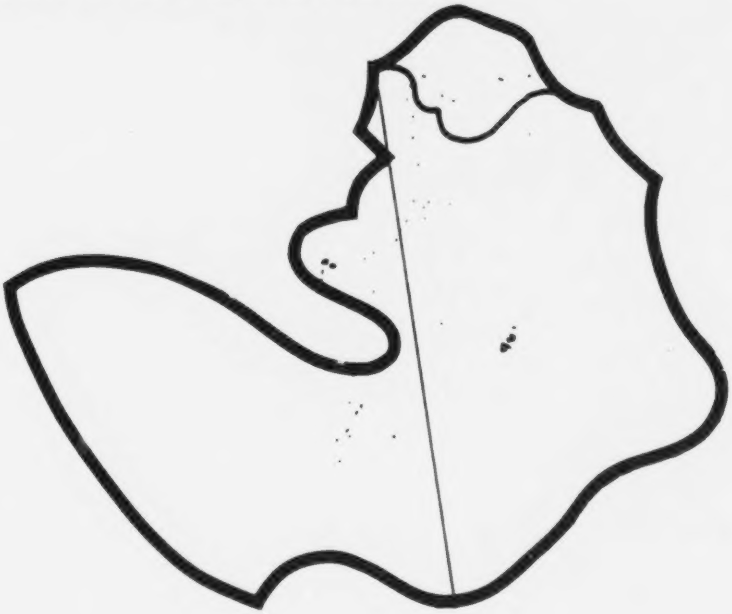

North American Plate
Eurasian Plate
Eurasian Plate
Pacific Plate
Philippine Plate
Arabian Plate
Caribbean Plate
Cocos Plate
South American Plate
Nazca Plate
African Plate
Australian-Indian Plate
Australian-Indian Plate
Antarctic Plate
0 1000 2000 3000
Miles
0 2000 4000 6000
Kilometers

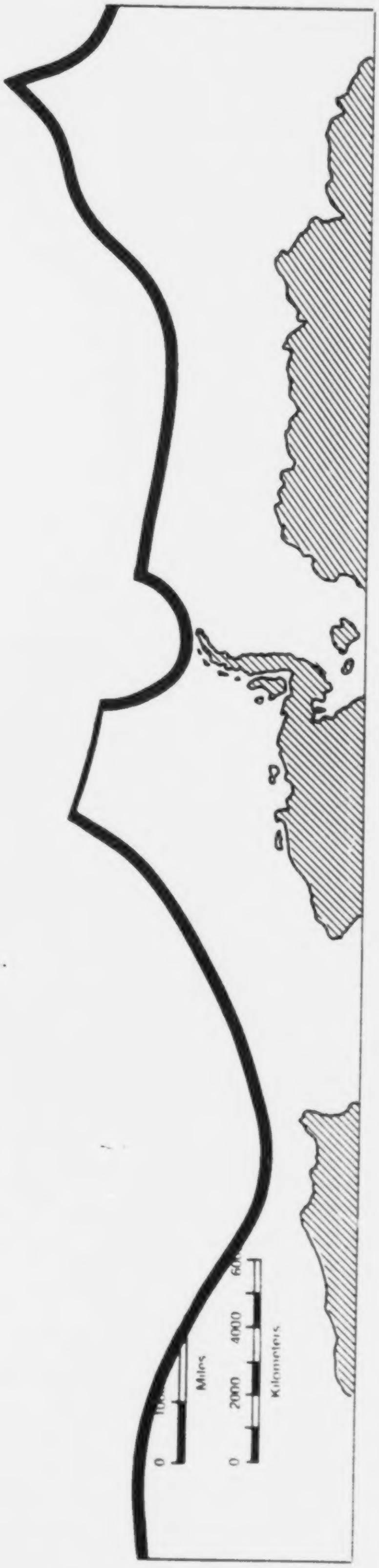
Earth Plate Puzzle Pieces

MASTER
3.2g



Back of Master 3.2g
Earth Plate Puzzle Pieces

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Miles
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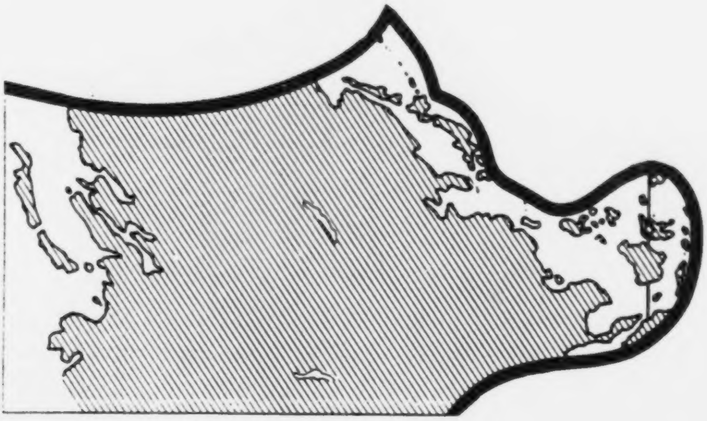


BUILDING AND EXPLORING AN ISLAND

3.3

ACTIVITY ONE

Island Hot Spots

Rationale

By comparing seamounts on the ocean floor with islands above sea level, students will come to recognize a common volcanic origin.

Objectives

Students will:

View a simulation of how island chains such as the Galápagos are formed.

Compare the amount of material below the water level to that above it, and relate this proportion to what we call *seamounts* (below sea level) and *islands* (above sea level).

Deduce why some islands in a chain such as the Galápagos are older than others.

Materials

- World map
- Overhead projector
- Galápagos Map (included with curriculum)
- Dark-colored gelatin desert mix
- Water to dissolve gelatin
- Plastic squeeze bottle of the type used for catsup and mustard
- Firm cardboard or file folder, at least 20 cm x 50 cm
- Nail or other sharp object for puncturing cardboard
- Scissors *(optional)*
- Construction paper
- Rectangular baking pan, dishpan, or foil roaster large enough to hold the cardboard
- Cold water

Procedure

Teacher Preparation

Hang the map included with the curriculum in full view of the class. Follow the recipe on the next page to make a batch of gelatin dessert. Assemble the materials you will need for the demonstration, and test the squeeze bottle full of gelatin. If necessary, enlarge its opening slightly. Just before class, fill the empty pan with cold water to a height of 2 cm.

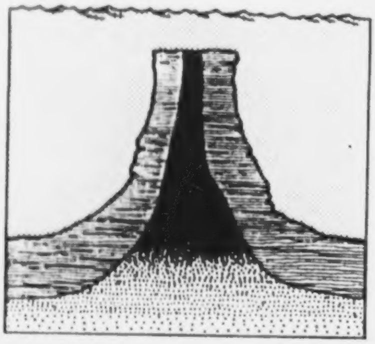
If you have not already done so, read Master 3.2c, Galápagos Geology, as preparation for teaching this class.

VOCABULARY

Hot spot - a volcanically active area on Earth's surface where a crustal plate rides over a rising plume of hot material from the mantle.

Is•land - a tract of land completely surrounded by water.

Sea•mount - a hot-spot volcano whose top was once above water. The tops of seamounts are worn flat by wave action as they sink back into the crust.



Seamount

Gelatin Dessert

1 170-gram (6 oz.) package gelatin dessert

18 mL (approx. 3/4 cup) boiling water

18 mL (approx. 3/4 cup) cold water

Pour the powdered gelatin mix into a heatproof measuring cup or pitcher. Add the boiling water and stir until no undissolved granules remain. Add the cold water and stir again. Pour the mixture into the plastic squeeze bottle. Refrigerate overnight or until solidified (at least 3 hours).

TEACHER TAKE NOTE

Be sure to follow these directions. Gelatin made according to the package instructions will be too soft to form peaks. Gelatin made with less water than specified here will be too firm to push up through the mouth of the bottle.

Procedure

A. Introduction

Ask students how they believe islands in mid-ocean form and what the islands look like underwater. Point out that islands in mid-ocean generally occur in chains. Some of these island chains are formed as a result of volcanic action at the boundaries between the Earth's crustal plates. These islands are found at mid-ocean ridges or at oceanic trenches. However, volcanic islands may also form inside plate boundaries, over hot spots deep within Earth's mantle. This activity models volcanic island building at these hot spots. The process is active today in the Galápagos Islands.

B. Lesson Development

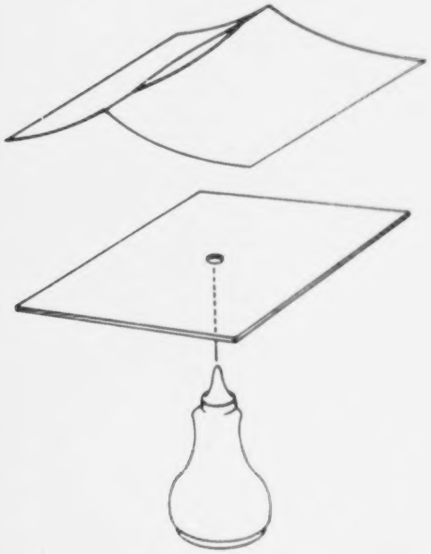
1. Review the contents of Lesson 3.2, Activity Three, emphasizing the layers of the Earth and crustal plate movement.

2. Point out some island chains or archipelagoes on the world map, including the Galápagos and Hawaiian Islands. Note the number of individual islands which appear above sea level in the island chains.

TEACHER TAKE NOTE

Be sure students understand that nearshore islands are generally not of volcanic origin, but are formed by other processes.

3. Tell students that in every island chain there are mountains both above and below sea level. Explain that some of those underwater mountains may be growing volcanoes that have not yet reached the surface and others may be extinct volcanoes that have eroded to below sea level. Then begin the demonstration.



4. Make a hole near the center of the cardboard just large enough to fit snugly around the mouth of the plastic squeeze bottle.

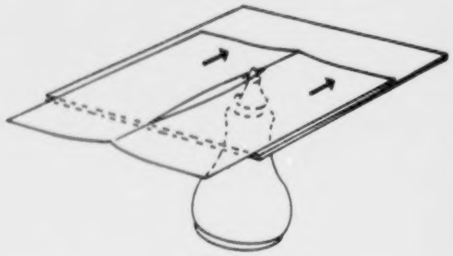
5. Fold the construction paper in half and cut a straight slit along the inside two-thirds of the fold, starting and ending well within the edges of the paper.

6. Push the mouth of the squeeze bottle up through the hole in the cardboard and position the construction paper on top of the cardboard so that the bottle mouth protrudes through one end of the slit in the construction paper.

7. Squeeze the plastic bottle, forcing gelatin up through the slit into a mound about 3 cm high on top of the construction paper. Ask students:

- What process is being modeled? (The pile-up of gelatin released by squeezing the bottle represents the formation of a seamount and potential island.)

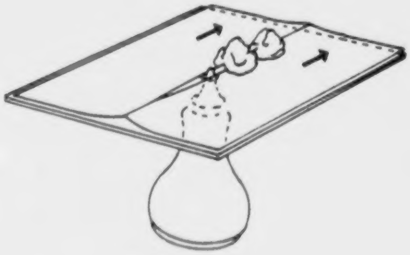
- What does the construction paper represent? (the seafloor crust.)



- What does the gelatin represent? (volcanic material, or lava)

- What does the bottle represent? (an underground magma chamber generated by a hot spot deep in the mantle)

8. Slide the construction paper slowly along the cardboard, keeping the paper slit over the mouth of the bottle. Vary the squeezing pressure on the bottle as you stop at five or six points to create a gelatin ridge of varying heights along the slit. Make the higher mounds above 3 cm in height and the lower ones below 2 cm.

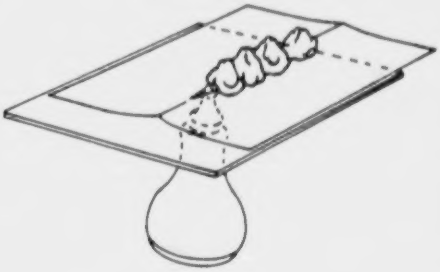


9. Carefully remove the construction paper with the gelatin from the cardboard and submerge it in the baking pan of cold water. This will illustrate the above/below water nature of volcanic island chains, which are sequentially formed and are primarily underwater features.

C. Conclusion

Challenge students to answer the following questions:

- In many island chains, the volcanoes on one end are active and those on the other end are extinct. How can you account for this fact? (The magma hot spot is under the newest volcano at one end of the chain.)



- The construction paper represented a section of the Earth's crust that moves over a stationary hotspot. The Galápagos are located on the Nazca plate. Isabela and Fernandina Islands are active volcanoes at the present time. In which direction is the plate moving? (from west to east) Which islands probably formed first? (Genovesa, San Cristóbal, Marchena, Pinta)

- In the demonstration, "islands" were formed one after the other. In the history of the Earth, new islands are formed very slowly. Does anyone know approximately how fast the Earth's crust moves? (several centimeters per year, or about the rate at which our fingernails grow)

- Islands on the old end of an island chain like the Galápagos (in this case, 5-7 million years old) are always lower than islands on the new end (approximately .7 million years old). Why is this so? (When the pressure of magma underneath an island is removed, the crust is likely to sink to some extent. As the island is built up by soil and vegetation, its increased weight may also cause it to sink lower, although this is more likely in Hawaii than in the Galápagos. Ocean waves, wind, and weather erode the tops of islands above sea level.)

This activity has been adapted from Ramsey et al., Modern Earth Science, *pages 96 and 97.*

ACTIVITY TWO

From Seafloor to Summit: A Profile Map of Fernandina Island

VOCABULARY

Cal•der•a - a steep-walled, flat-floored depression at the top of a volcano.

El•e•va•tion - in maps, the altitude above sea level. Elevation provides a more objective measurement than height, which is altitude above the surrounding area.

Pro•file - a drawing showing a vertical section (side view) of the ground along a surveyed line.

Shield vol•ca•no - a gently sloping volcano of the type most common in the Galápagos.

Stra•to vol•ca•no - a steep-sided volcano composed of layers of lava and volcanic ash.

To•po•graph•ic map (also known as a **contour map**) - a map that uses contour lines to show the three-dimensional features of a place.

Rationale

In this activity students will translate a cross section from a topographic map of Fernandina Island into a profile, illustrating the depth of the sea floor at the base of this type of volcano, the depth of the caldera, and the gently sloping shape typical of shield volcanos.

Objectives

Students will:

Make a profile from a topographic map.

Observe that most of a volcanic island is underwater and that its bottom may reach great depths.

Materials

- Galápagos Map (included with the curriculum)
- Student copies of Master 3.3a, Topographic Map of Fernandina
- Plain drawing paper
- Pencils
- Transparency made from Master 3.3a, Topographic Map of Fernandina
- Student copies of Master 3.3b, Fernandina Profile Graph
- Overhead projector
- Overhead transparency marker
- 30-cm rulers

Procedure

A. Introduction

Distribute copies of Master 3.3a, the topographic map, and have students look at it. Can they locate the caldera of the volcano? Can they find the island's shoreline? (Don't press for answers at this point, since students will be learning to interpret the map in the course of the exercise.) Ask the students for their impression of what the island is like underwater. How far down does it go? How steep are its sides?

Distribute drawing paper and ask the students to draw what they think is the shape of the volcano above water, showing the depth and width of the caldera. (Most of these quick sketches will probably show a steep-sided strato volcano.) Do not collect the drawings. Explain that this activity will provide a profile, or side view, of the volcanic island both above and below sea level.

B. Lesson Development

1. Display the map of the Galápagos Islands provided with the JASON curriculum and have the students locate Fernandina.

2. Distribute student copies of Master 3.3b, the graph.

3. Project the transparency of the topographic map of Fernandina. Tell students that map makers draw lines of equal *elevation* (or altitude above sea level) by joining surveyed points of equal elevation that have been plotted on a map. These lines are called *contour lines*. Instruct students to join the soundings (represented by the numbers on the left) on their own maps to draw contours of the sea floor off Fernandina Island. Connect all the 200 m soundings on the transparency to demonstrate. If they have trouble deciding how to join the soundings of equal depth, have them look at the contours on the map and point out that the contours underwater should look the same as those above water (on the right).

4. After the students have joined the soundings to create contours of the ocean floor, have them start at the point marked A on their maps and follow along the line toward point B (southeast). Remind them that they start out below sea level and with each contour line they cross they either gain or lose elevation. Ask them to describe what would happen if they could walk along that line. (Assuming they could breathe underwater, they would be going from deep water [1600 m] to shallower water until they reached the surface of the water on Fernandina's beach.) Ask the students to continue their journey toward point B and describe what is happening. (They continue to gain altitude, climbing the side of the volcano until they reach the 1200-meter mark.)

Tell the students that when contour lines form a closed circle, map makers use lines with hatch marks to indicate that elevation inside the circle is lower than that outside the circle. The hatch marks point toward the lower elevation. Ask students what they think the hatch-marked lines on their maps define. (the caldera on Fernandina's summit) Tell them that scientists draw profiles (side views) of maps to help us understand what the surface of the Earth that is represented on the map looks like. In the next part of this activity they will draw a profile of Fernandina.

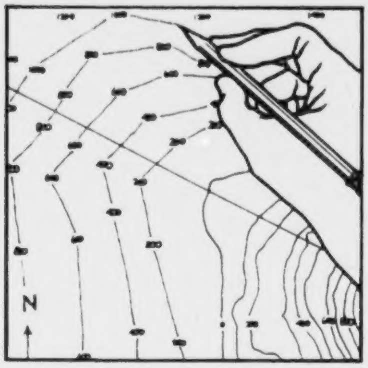
5. Give these directions for completing the profile. Demonstrate the process on the transparency as you proceed.

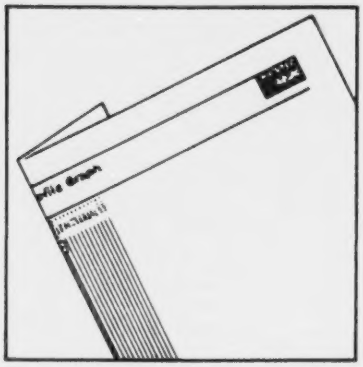
- Carefully fold the graph master (3.3b) along the line marked *Sea Level*.

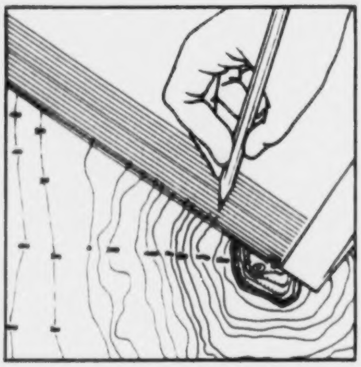
- Place the folded paper on Master 3.3a, Topographic Map of Fernandina, along the line marked A-B so that it covers the top part of the map and the two As and Bs line up.

- Locate the point where the sea level contour goes under the folded paper, mark it on the fold, and label it *Sea Level*.

- Move along the fold, marking the point where each of the other contour lines above water goes under the fold. Label



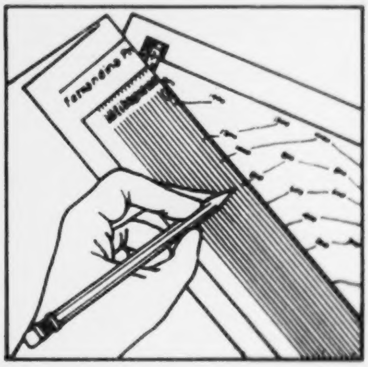




TEACHER TAKE NOTE

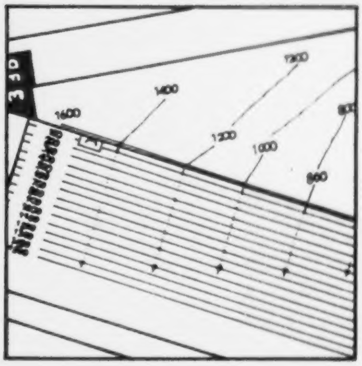
Explain to students that the reason the lines on Master 3.3c are so close together is to represent the actual shape of the volcano as closely as possible. If the lines were further apart, the shape would be steeper than it actually is. Even with the lines on the master as close as they are, there is still some vertical exaggeration.

each with the number it has on the Fernandina master.



- When all the points above water have been marked (including the unnumbered, hatch-marked lines inside the caldera), and those above the caldera's rim have been labeled, turn over the folded paper and place it on the map so it covers the bottom of the map and points A and B are aligned.

- Repeat marking and labeling the points where the sounding lines go under the fold. (Note that the underwater lines are marked every 200 meters, instead of every 100 meters as on land.)

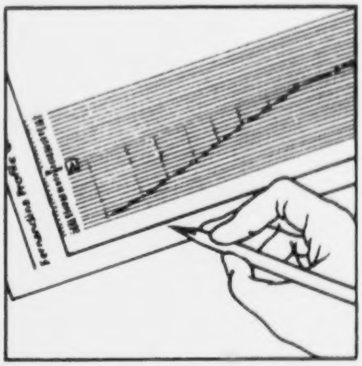


- After all the points have been marked unfold the paper and draw vertical lines, straight down on the sounding side and straight up on the land side, to the appropriate elevation lines. (A ruler will be helpful at this point.) Mark a dot where each line ends. Mark six descending dots a little way apart inside the caldera, at the far right edge of the graph.

- When all the dots have been placed on the lines, connect the dots with a smooth line. Label the caldera and its rim.

C. Conclusion

Invite students to compare their profiles with the rough sketches they made at the beginning of the lesson. What differences do they see? Ask for comments on the amount of the island underwater compared to that above, and on the general shape of the above-water portion of the volcano. Build a class discussion around these questions:



- On the map, what does the distance from one contour line to another signify? (gain or loss of elevation)

- Notice what happens to the distance between contour lines at the caldera. Judging from their profile, what do close-together contour lines signify? (steep slopes)

-On the south floor of the caldera (below B) are two small features indicated by rings. Do the contour lines tell us if they are depressions or elevations? (Since they do not have hatch marks, they are elevations.)

- Is Fernandina a strato volcano, with steep sides, or is it a gently-sloping shield volcano? (It's of the shield type.)

- How do you suppose the caldera became so large? Was it filled with lava once? Was it blown out? Did the center collapse? (Accept student ideas without comment. The next activity in this lesson illustrates caldera formation.)

Adaptations

For younger students

If necessary, use some of the references in the unit bibliography to introduce topographic maps and volcanism.

For older students

1. You may not need to model the process on the transparency for high school students, or you may take only the first few steps with the class.

2. Remind students that their profile does not depict the other side of the island. Have them make a drawing, more

detailed than their first sketch, to extrapolate what the uncompleted side looks like. Students may use the map of the Galápagos included with the curriculum as a reference.

ACTIVITY THREE

Build a Volcano

Rationale

This lesson enables students to understand how a volcano is built over time by numerous eruptions of molten rock and other material, such as ash, and how it may develop a caldera at its summit.

Objectives

Students will:

Model two formations that result from different materials and different kinds of flow in volcanic eruptions.

Observe the differences between shield and strato volcanoes.

Simulate the collapse of a shield volcano and the formation of a caldera.

Materials

- Sharp crayons or felt markers with a chisel edge in three different colors, one set for each group of three students
- Student copies of Master 3.3c, Build a Volcano, two for each group
- Student copies of Master 3.3d, Build-a-Volcano Cards (five two-sided pages)
- Paper clips
- Pencils
- Scissors

Procedure

Teacher Preparation

Make two copies of Master 3.3c and one set of the cards on Master 3.3d for each small group of three students. (For each group, cut apart one complete set of the Build-a-Volcano cards and separate the two subsets, shield volcano cards and strato volcano cards, with paper clips.)

If necessary, review Master 3.2c, Galápagos Geology, Teacher Background Reading, about the different types of lava flows and their characteristics.

A. Introduction

With the class, briefly review Activity Three in Lesson 3.2 of this unit, dealing with the structure of the Earth's interior, plate tectonics, and the relationship of volcanoes to seismic activity. Supply only as much detail as your class needs to understand why, in the activity that follows, they must begin drawing each line at the vent directly above the magma chamber.

VOCABULARY

Cal•der•a - a steep-walled, flat-floored depression at the top of a volcano.

Cra•ter - a funnel-shaped depression at the top of a volcano marking the vent through which volcanic products are ejected.

Mag•ma - molten rock material within the Earth. When magma erupts to the surface it is called **lava.**

Shield vol•ca•no - a gently sloping volcano of the type most common in the Galápagos. Shield volcanoes are formed almost entirely by fluid lava flow.

Stra•to vol•ca•no - a steep-sided volcano formed by layers of lava and volcanic ash.

B. Lesson Development

TEACHER TAKE NOTE

To determine who goes first in each group, ask each student to choose one of the colored markers. When all have chosen, call out the name of a color. The student in each group who has chosen that color will take the first card.

TEACHER TAKE NOTE

Be sure students understand that this is a two-dimensional representation of a three-dimensional event. As they build the lava layers, they are working on a cross section of a volcano.

1. Divide the class into groups of three students each. Provide each group with three markers or crayons, two copies of Master 3.3c, and two sets of the prepared cards.

2. Ask students to describe what they see on Master 3.3c, Build a Volcano. Explain that the horizontal line represents an area of Earth's surface and the vent is an opening into a magma chamber. Tell students that they are going to create models of two different kinds of volcanoes by making marks of a specified length and width on the two identical masters.

3. Instruct students in each group to place the two packs of cards in the center of their work area and label one of the two copies of Master 3.3c (Build a Volcano) *Shield Volcano*.

4. Beginning with the shield volcano cards, students will take turns drawing a card from the pack, reading its instructions aloud, and making a mark on the first master of the type specified. Give these instructions:

- Each card represents a lava flow or some other eruption in the history of a volcano. Every mark must begin above the magma chamber, at the point marked *Vent* on the drawing, must be either thick or thin, and must "flow" for a short, medium, or long distance, as specified by the card.

- If the card specifies a thick flow, draw a line approximately 2 mm wide with the side of a crayon or the flat edge of a chisel-tip marker. If it specifies a thin flow, use the point of a crayon or the edge of a marker to make a mark approximately 1 mm wide.

- If the card specifies a very short flow, extend the line for about 5 mm down the side of the volcano. Show a short flow with a line about 10 mm long; a medium flow with a 20-mm line; and a long flow with a 30-mm line.

- If the card specifies ash, draw dots and dashes of the thicker width (2 mm).

5. When the first deck has been used up, ask students to take the second Build a Volcano sheet, label it *Strato Volcano*, and repeat the process with the second deck, the strato volcano cards. When all the cards have been drawn and their instructions followed, ask students to describe the two types of volcanoes pictured. (Because a strato volcano is formed by lava flow mixed with ash and distributed fairly evenly on both sides of the magma chamber, it has high, steep sides. The shield volcano is formed by thin lava flows without much ash, so its sides slope gently.)

6. Have the groups of students compare their drawings. Do all the shield drawings look similar to each other? All the strato drawings? (Yes. They will not be identical because students are not using precise measurements, but except for the colors used, the drawings should look similar.)

7. Give these instructions for the student groups to model caldera formation:

- Use the pencil to draw vertical lines on the shield volcano drawing (Master 3.2c), from the widest point in the magma chamber upward to the surface of the volcano. (The lines will be on both sides of the magma chamber.)

- Use the scissors to cut toward the surface along the vertical lines, starting at the magma chamber. Then cut across the top, joining the sides. Do not cut across the bottom. There will be a loose flap of paper in the center of the page.

- Pinch the flap at the base of the volcano, slide it down, and crease it so it stays in place. What do you observe? (The center drops.)

8. Explain that a caldera forms by several stages. First, additions to the magma chamber near the surface cause the surface to swell like a balloon, cracking the rocks and creating ring fractures above the chamber—something like the lines students cut on their drawings, but in the round. When the magma erupts and empties the chamber, support is withdrawn from the bottom of the broken block and it drops down into the vacated magma chamber. Ask students to slide their paper flaps down again to see the collapse.

C. Conclusion

1. Ask these discussion questions to review what students have observed:

- Does the sequence, or order, of the eruptions affect a volcano's shape? (No. If time allows, students can demonstrate this by shuffling the cards in either set and repeating the exercise with a clean worksheet.)

- What does determine the difference between the two types of volcano? (Thin lava flow creates shield volcanoes. Thicker flow mixed with volcanic ash creates strato volcanoes.)

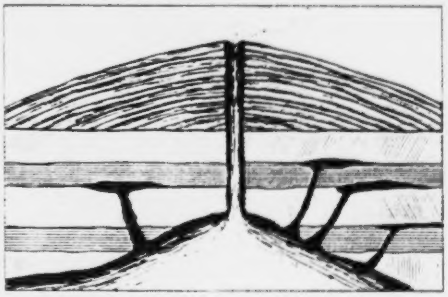
- What causes the collapse of a shield volcano, resulting in a caldera? (The pressure of magma inside the volcano weakens the block of rock nearest the top, causing ring fractures and other cracks. When the magma is ejected, its support is withdrawn and the summit drops to fill the space left empty.)

- In a volcano that has just formed a caldera, where would the next lava flow most likely occur? (along the fracture zone [the unsupported, broken edges] bordering the collapsed area)

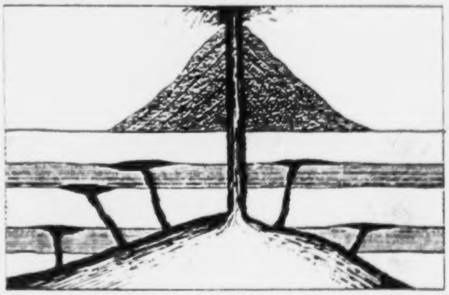
- What would happen if new lava were added to the floor of the collapsed volcano? Could the process of caldera formation be repeated? (Yes. The caldera would continue to grow deeper. Tell students that Fernandina in the Galápagos is a typical shield volcano. Its caldera has been enlarged several times, most recently in 1968.)

2. Summarize the content of this activity and the one preceding it: Each volcano's shape is determined by a unique combination of volcanic events. Many of the Earth's volcanoes are under water and have not been studied. Those we know about fall into two main types, shield volcanoes and strato volcanoes. Galápagos volcanoes are of the shield type.

Shield Volcano



Strato Volcano



Adaptations

For younger students

Perform this activity as a demonstration, then have students build clay models of the two types of volcanoes.

For older students

Relate strato volcanoes to convergent plate boundary activity and shield volcanoes to hot spots, drawing on the teacher background material for Lesson 3.2. Refer back to Activity One, Hot Spots.

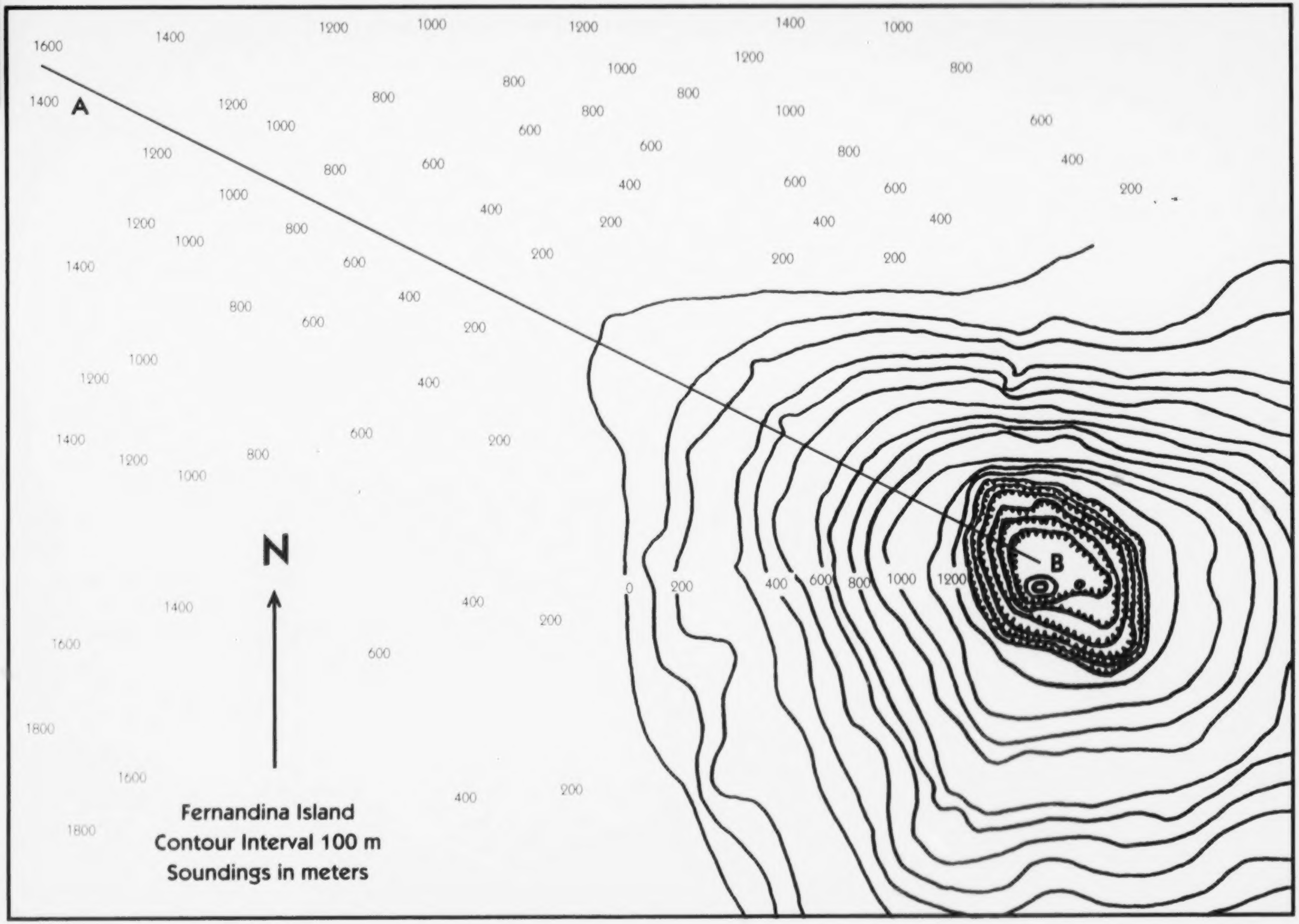
For all ages

Challenge students to find pictures and written material on some well-known volcanoes: Mount St. Helen's, Shasta, Fuji, Vesuvius, Mauna Loa, and others. When they share what they have learned, be sure they are prepared to tell whether each is a strato or a shield volcano.

This activity was suggested by Hesser (1987), Focus on Earth Science, *Columbus, OH: Merrill Publishing Company.*

MASTER 3.3a

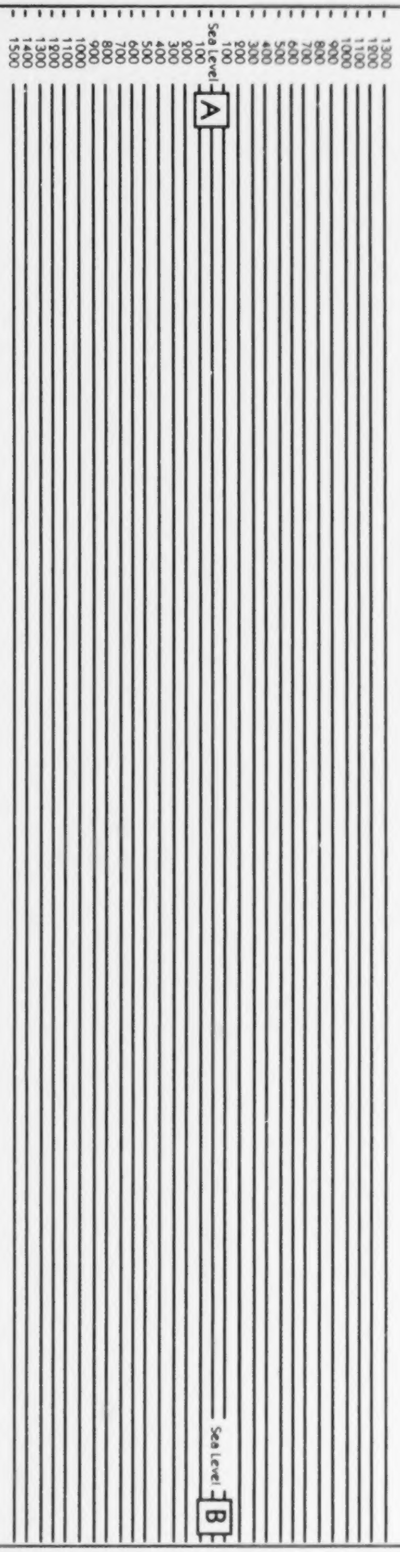
Topographic Map of Fernandina Island


A
B
N
0
200
400
600
800
1000
1200
1400
1600
1800

Fernandina Island
Contour Interval 100 m
Soundings in meters

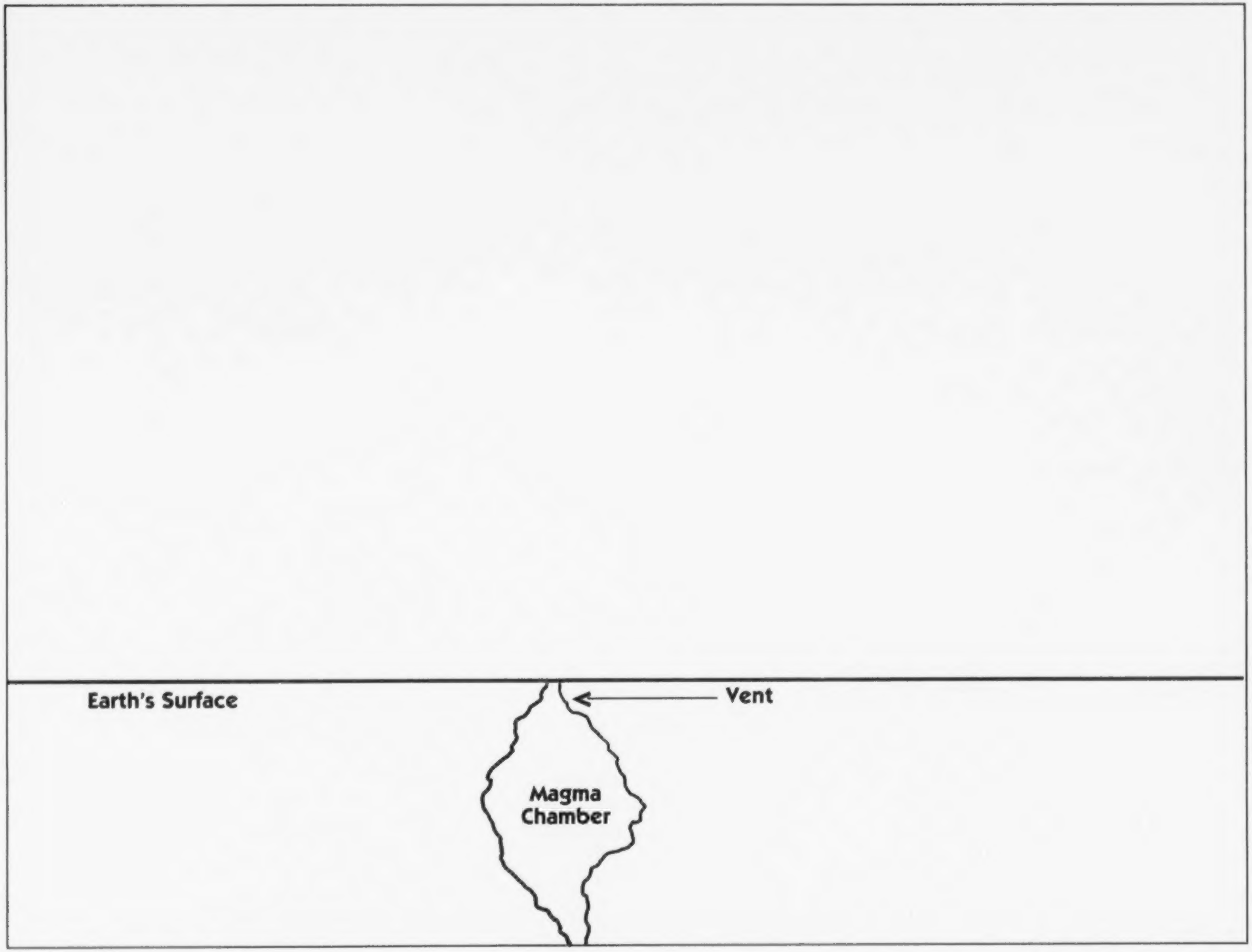
MASTER 3.3b

Fernandina Profile Graph



MASTER 3.3c

Build a Volcano


Earth's Surface
Vent
Magma Chamber

Build-a-Volcano Cards (Shield)

MASTER
3.3d

-Left- Very Short Flow
-Right- Long Flow
(Thin)

-Left- Long Flow
-Right- Long Flow
(Thin)

-Left- Medium Flow
-Right- Short Flow
(Thin)

-Left- Short Flow
-Right- Long Flow
(Thin)

-Left- Short Flow
-Right- Medium Flow
(Thin)

-Left- Long Flow
-Right- Short Flow
(Thin)

-Left- Long Flow
-Right- Medium Flow
(Thin)

-Left- Medium Flow
-Right- Medium Flow
(Thin)

-Left- Medium Flow
-Right- Long Flow
(Thin)

-Left- Ash Eruption
-Right- Ash Eruption
(Thin)

-Left- Very Short Flow
-Right- Very Short Flow
(Thin)

-Left- Very Short Flow
-Right- Short Flow
(Thin)

Build-a-Volcano Cards, back

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

-Left-	**-Right-**
Medium	Medium
Flow	Flow

(Thin)

-Left-	**-Right-**
Medium	Medium
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Short	Long
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Short
Flow	Flow

(Thin)

-Left-	**-Right-**
Long	Short
Flow	Flow

(Thin)

-Left-	**-Right-**
Medium	Medium
Flow	Flow

(Thin)

-Left-	**-Right-**
Medium	Medium
Flow	Flow

(Thin)

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build a
Shield Volcano

Build-a-Volcano Cards (Strato)

MASTER
3.3d

-Left-
Ash
Eruption

-Right-
Ash
Eruption

(Thick)

-Left-
Short
Flow

-Right-
Medium
Flow

(Thick)

-Left-
Very
Short
Flow

-Right-
Short
Flow

(Thick)

-Left-
Long
Flow
(Thin)

-Right-
Short
Flow

(Thick)

-Left-
Medium
Flow
(Thin)

-Right-
Medium
Flow

(Thick)

-Left-
Short
Flow

-Right-
Very
Short
Flow

(Thick)

-Left-
Medium
Flow

-Right-
Short
Flow

(Thick)

-Left-
Medium
Flow

-Right-
Long
Flow
(Thin)

(Thick)

-Left-
Very
Short
Flow
(Thin)

-Right-
Very
Short
Flow

(Thick)

-Left-
Short
Flow

-Right-
Short
Flow

(Thick)

Build-a-Volcano Cards, back

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

Build a Strato Volcano	Build a Strato Volcano
Build a Strato Volcano	Build a Strato Volcano
Build a Strato Volcano	Build a Strato Volcano
Build a Strato Volcano	Build a Strato Volcano
Build a Strato Volcano	Build a Strato Volcano

Build-a-Volcano Cards (Strato)

MASTER
3.3d

-Left- Ash Eruption
-Right- Ash Eruption
(Thick)

-Left- Short Flow
-Right- Medium Flow
(Thick)

-Left- Medium Flow (Thin)
-Right- Medium Flow
(Thick)

-Left- Very Short Flow (Thin)
-Right- Very Short Flow
(Thick)

-Left- Short Flow
-Right- Short Flow
(Thick)

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

Build a
Strato Volcano

3.4

WATER ON THE MOVE: OCEAN CURRENTS ON A GLOBAL SCALE

ACTIVITY ONE

Creating Water Currents with Wind

Rationale

Students generally know that wind causes the waves that carry its energy across the surface of a body of water. They may not know about the role of wind in producing surface currents. This simulation shows the formation of currents, horizontal movements of surface water that create invisible rivers in oceanic waters, including those that surround the Galápagos Islands.

Objectives

Students will:

Create waves and a current on the surface of a body of water.

Compare the action of waves and currents.

Materials

- Newspapers for covering countertops and floor
- Hair dryers
- Rectangular plastic tubs, 4 liter capacity or larger
- Food coloring
- Tap water
- Lab aprons
- Transparency made from Master 3.4a, Prevailing Winds of the Equatorial Pacific
- Overhead projector
- Globe, classroom wall map, or Master 1.2a, World Map
- Student copies of Master 3.4b, Map of the Equatorial Pacific
- Transparency made from Master 3.4c, Equatorial Pacific Currents
- Pencils or pens

Procedure

Teacher Preparation

The day before you plan to do this activity, ask students to bring hair dryers from home. The size of student cooperative groups will depend on the number of hair dryers available.

Just before class, have students help you spread newspapers on all work surfaces and the floor directly under them. If lab aprons are available, have students wear them. They will get wet.

VOCABULARY

Cur•rent - a part of a fluid body that moves continuously in a single direction.

Coun•ter•cur•rent - a current that flows in the opposite direction from a major current.

El Ni•ño - a set of events caused by periodic reversals in the weather patterns of the eastern Pacific Ocean from cool and dry to warm and wet.

Pre•vail•ing - in effect most often at the present time.

Wave - the up and down movement of water that carries energy across its surface.

TEACHER TAKE NOTE

The activities in this lesson are a series in which each builds upon the preceding one. Plan for enough time to do them all.

A. Introduction

Project the transparency made from Master 3.4a, Prevailing Winds of the Equatorial Pacific. Tell students that the friction of wind blowing across the surface of ocean water creates waves and sets up currents. These currents are important to life on Earth because they moderate temperatures, bringing warm water into the higher latitudes and cool water into the lower latitudes. These currents also bring nutrients to nutrient-poor waters. Any change in the currents affects the temperature, humidity, and life processes of areas adjoining the coastal regions. This activity and the three that follow will help students understand how currents affect the Galápagos Islands.

B. Lesson Development

1. Leave the transparency (Master 3.4a) on the screen as you divide students into groups for the activity. Supply each group with food coloring, a hair dryer to simulate wind action, and a plastic tub about two-thirds full of water for an ocean. Give these directions to the groups:

- Blow the hair dryer across the top of the simulated ocean. (Use the cold air setting if available.) Notice the waves that form and move across the water's surface. How do they move? (Their movement tends to be choppy and up and down.)

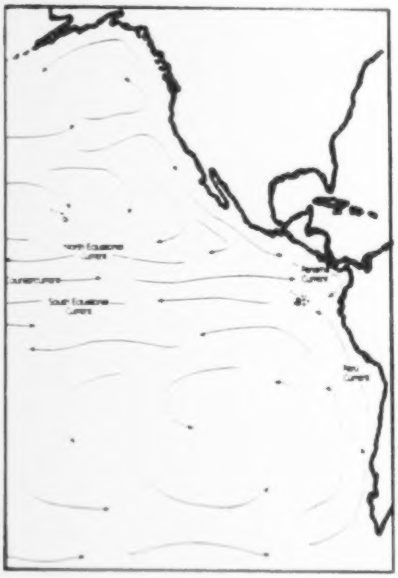
- Turn off the dryer. Add a drop of food coloring to the water near one end of the tub. (Be careful: It stains clothing!)

- Turn on the dryer and blow from the end where the coloring was placed toward the other end of the tub. Observe the movement of colored water across the water's surface. This ribbon of colored water indicates a current.

TEACHER TAKE NOTE

Warn students that splashing water on or near the hair dryers could cause serious electrical shocks. Emphasize that if a hair dryer drops in the water, they must leave it there until they have unplugged the cord. At the first sign of any horseplay involving hair dryers, halt this activity immediately.

2. Direct students' attention to the transparency made from Master 3.4a, Prevailing Winds of the Equatorial Pacific. Ask students to identify the land masses pictured and locate the Galápagos Islands. (Refer to the globe or world map if necessary. The Galápagos Islands are relatively tiny land masses in the Pacific Ocean.) Roughly sketch in the Equator on the transparency to reinforce the fact that the Galápagos Islands cluster near it, and so are located in both the northern and southern hemispheres. North and South America are on the right; India is at the top left, and Australia at the bottom left. Explain that this is a map of normal wind patterns in the equatorial Pacific.



3. Pass out copies of Master 3.4b, Map of the Equatorial Pacific. Have students refer to the overhead, then draw arrows on their maps predicting the pattern of currents in the equatorial Pacific.

4. Project the transparency of Master 3.4c, Equatorial Pacific Currents. Ask students to compare the pattern of the currents with the arrows they have drawn. There should be rough similarities. Explain that although currents do follow the direction of the wind, the two diagrams do not account for all the movements in a body of water. In addition to waves and currents, oceans also contain *countercurrents*, currents created when water flows into a low area to take the

place of water blown away by the wind. Countercurrents flow in the opposite direction from the major currents.

C. Conclusion

Set the tubs of water aside for later use and gather the class for a discussion. Ask these questions:

- What causes waves and currents? (the action of wind on water)
- What are the differences between waves and currents? (In waves, the water moves up and down as energy moves across its surface. A current is a stream of water moving across the surface of a water body in a specific direction. Also, waves move faster than currents.)
- If you were stranded in the middle of the ocean, which would be more likely to help you get to land, waves or currents? (Probably neither. The current is a river on the surface of the water. It would carry you along, but not necessarily toward land. Waves would merely lift you up and down.)
- Where does new surface water come from after the wind starts a current? (from the sides of the stream or below it)
- What is a countercurrent? (a current that flows in the opposite direction from a major current)
- How do countercurrents form? (They are created when water flows in to take the place of water blown away by the wind.)

Summarize the discussion. Tell students the next activity will demonstrate more about the direction of currents.

TEACHER TAKE NOTE

Do not collect the map worksheets. Students will use them again in Activity Two.

ACTIVITY TWO

Sloshing in the Pacific Ocean

Rationale

Periodic reversals in the weather patterns of the eastern Pacific Ocean—from cool and dry to warm and wet—are designated *El Niño* phenomena. A significant contribution to such changes is thought to be an increasing flow of warm water which has been built up in the western Pacific by prevailing wind and water currents, pushing the water westward faster than it can flow back to the east. When these currents shift, water sloshes back across the Pacific, overriding the influence of normal cold currents and upwellings in the eastern Pacific. Warm surface water replaces cold water, bringing increased humidity and precipitation. Prolonged abnormal conditions such as those during an El Niño event affect everything that lives in the Galápagos.

VOCABULARY

El Ni•ño - a set of phenomena caused by periodic reversals in the weather patterns of the eastern Pacific Ocean from cool and dry to warm and wet.

Objectives

Students will:

Demonstrate water *mounding* and *leveling*.

Relate the activity to processes that occur in the world's oceans.

Explain in their own words how the water level is equalized across a wide expanse of ocean.

Materials

- One large piece of plywood or hardboard, about .6 cm (¼ in.) thick
- Newspapers for covering desks or counters and floors
- Lab aprons
- Transparency made from Master 3.4a, Prevailing Winds of the Equatorial Pacific (from Activity One)
- Overhead projector
- Student copies of Master 3.4b, Map of the Equatorial Pacific (held over from Activity One)
- Transparency made from Master 3.4c, Equatorial Pacific Currents (from Activity One)
- Student copies of Master 3.4c, Equatorial Pacific Currents
- Rectangular plastic tubs filled with water, one for each group (set aside from Activity One)
- Two 30-cm rulers for each group
- Marking pens
- Paper and pencils for recording data

Procedure

Teacher Preparation

For each group of students, cut a piece of plywood or hardboard .6 cm thick to approximately the same width as the plastic tub. Make the board high enough to reach the bottom of the tub and extend 10 to 15 cm (4-6 in.) above it.

If you cleaned up after Activity One, have students help you protect the work area with fresh newspapers.

TEACHER TAKE NOTE

Help students stay oriented by reminding them that an easterly wind blows *from* the east toward the west. If questions arise, it might also be necessary to explain that the eastern Pacific is identified as such from a global perspective, even though it abuts the west coasts of North and South America.

A. Introduction

Project the transparency made from Master 3.4a, Prevailing Winds of the Equatorial Pacific. Explain to students that these are normal wind patterns. Ask them to share their predictions from Activity One about the directions of surface currents in the equatorial Pacific. Pass out copies of Master 3.4c, Equatorial Pacific Currents, and project the transparency made from that master. Invite students to compare these charts to their maps from Activity One (Master 3.4b). Remind them that the currents on the map are like large rivers in the ocean carrying water from east to west. When normal wind direction prevails, these currents will carry water slightly faster than it can flow back, so that water is mounded up in the western Pacific Ocean. This activity will simulate that process.

B. Lesson Development

1. Divide students into working groups of at least three people. Distribute materials and give these directions:

- If necessary, refill your plastic tub to approximately one-third full.

- Choose two students to hold the rulers upright, one at each end of the tub. Record the readings on both rulers with their bottoms touching the bottom of the tub.

- Label one end of the tub *East* and the other end *West*.

- Place the board into the water at the east end of the tub. Grasp it with both hands and hold it as upright as possible.

- Take turns holding the rulers and pushing the board gently toward the other end of the tub. As one student pushes the board, other team members observe and record the maximum and minimum water levels at each end of the tank.

- On each turn, record the maximum level at about three-quarters of the way across the tub (hopefully before too much water has sloshed out), then remove the board by pulling it rapidly straight up. Watch and record further observations of water behavior.

2. Remove the tubs and water. Direct students to mop up as necessary and return to their seats.

3. Review the activity with the class. Students should have observed that the water mounded up as the board was pushed and a back and forth wave motion was set up in the water, with the mound of water traveling to the low end and bouncing back. In reality, sea level in the western Pacific is about 10 cm above the global average, while sea level in the eastern Pacific is about 5 cm below the average. When the wind patterns that maintain this situation vary, the high water in the west moves across the ocean toward the east and bounces off the continent of South America. The next activity will help students understand how these changes can affect the Galápagos weather and sea surface temperatures.

C. Conclusion

Use these questions to conclude the review:

- In the demonstration, what did the moving board represent? (the force of winds and currents pushing water across the ocean)

- How does water mound up in the western Pacific? (Wind-created currents push the water toward the west faster than it can flow back to the east.)

- What will happen to the currents in the equatorial Pacific when the wind changes direction? (The water that is mounded up in the western Pacific will slosh back across to the eastern Pacific.)

- How will that change affect the depth of the western and eastern Pacific? (The sea level of the western Pacific will fall and that of the eastern Pacific will rise.)

ACTIVITY THREE

El Niño, Currents, and Climate

VOCABULARY

Coun•ter•cur•rent - a current that flows in the opposite direction from a major current.

Ped•es•tal up•well•ing - a flow of cold, deep water that runs into the coast and is forced upwards to the surface of a water body .

Up•well•ing - a flow of cold, deep water to the surface of a water body. In an ocean upwelling, surface water near the coast is carried out to sea by winds and replaced by cooler subsurface water.

Un•der•cur•rent - a current that flows under other currents, usually in a different direction.

Rationale

The Galápagos Islands lie in a crossroads of oceanic currents that bring both cool (temperate-zone) and warm (tropical) water to the islands. These currents change with the seasons, modifying the climate both on land and in the surrounding coastal waters in ways that are regular and predictable. The unique land and oceanic life of the Galápagos Islands, which includes both temperate-zone organisms, like the sea lion, and tropical organisms, like the butterflyfish, is made possible by these crossing currents and their effect on climate.

An occasional disruption in the ocean currents, called an *El Niño event*, surrounds the islands with relatively warmer water, changing the climate and living conditions for everything that lives in the Galápagos.

Objectives

Students will:

Color-code a map to show the major currents affecting the Galápagos.

Interpret a diagram showing seasonal ocean conditions and shifts in upwelling.

Relate ocean conditions to weather and climate.

Consider the effects of changing currents on ocean and terrestrial life.

Materials

- Transparency made from Master 3.4c, Pacific Ocean Currents
- Overhead projector
- Globe, classroom wall map, or Master 1.2a, World Map
- Student copies of Master 3.4c, Pacific Ocean Currents (from Activity Two)
- Transparency made from Master 3.4d, Currents in the Galápagos Area
- Transparency made from Master 3.4e, Currents and Upwellings
- Student copies of Master 3.4e, Currents and Upwellings
- Colored pencils or crayons

Procedure

A. Introduction

Remind students that the Galápagos Islands cluster around the equator, with some of the islands in the northern hemisphere and others in the southern hemisphere. The Galápagos Islands do not experience summer and winter climates as we know them. They do, however, experience seasonal weather changes, because their climate is affected by ocean currents that flow to the islands.

B. Lesson Development

1. Project the transparency made from Master 3.4c, Pacific Ocean Currents, and distribute copies to the students. Begin by orienting the students so they know what portion of the ocean the map shows. Refer to the globe or world map if necessary. The Galápagos Islands are relatively tiny land masses in the Pacific Ocean. Roughly sketch in the Equator on the transparency to reinforce the fact that the Galápagos Islands cluster near it, and so are located in both the northern and southern hemispheres.

2. Point out the currents on the transparency, beginning with the currents that flow from the north. Indicate the North Equatorial Countercurrent that carries warm water toward the east and sets in motion the Panama Current that carries warm water to the Galápagos. Have the students color these currents red on their maps to signify warm water.

3. Project the transparency made from Master 3.4d, Currents in the Galápagos Area. Point out the two currents that flow to the Galápagos from the south, the Peru Oceanic Current and the Peru Coastal Current. These are cold currents. Have students color these currents blue to signify cold water.

4. Indicate that the warm currents flowing from the north and the colder currents from the south meet near the equator, then turn to flow toward the west, forming the South Equatorial Current, or SEC. Ask students to hypothesize about the temperature of the SEC. (They may deduce that it will be between that of the warm Panama Current and those of the cooler Peru Currents.) Have them decide how to color-code the SEC. (Students might choose to use both red and blue, a stippled pattern, or a third color.) Explain that beneath the SEC, in deeper waters, the Equatorial Undercurrent is flowing in the opposite direction.

5. Project the transparency made from Master 3.4e, Currents and Upwellings, and pass out student copies. Emphasize that the currents flowing to the Galápagos determine the region's weather and seasonal changes. If the currents are warm, water evaporates from the ocean, so there is much rain; if they are cold, less evaporation takes place, so there is less rain. Consequently there are two seasons in the Galápagos. Write this on the transparency or on the chalkboard:

Dry season (cool weather) - June through December

Wet season (warm weather) - January through May

6. Direct students' attention to the diagrams on Master 3.4e, Currents and Upwellings. Be sure they understand that they are seeing a profile view of Fernandina illustrating how currents flow to the island.

7. With the class, interpret the current flow pictured for January. Point out the surrounding warm water (about 25°C) that flows from currents to the north. Under this, a colder current flows to the island, bumps into it, then flows upward to the surface along the coast. This flow of cold water to the surface is called a *pedestal upwelling*, or a *forced upwelling*.

TEACHER TAKE NOTE

Some students may find it puzzling that a current from the north is warm and a current from the south is cold. Help these students to move beyond their northern hemisphere frame of reference. Explain that in the southern hemisphere, the farther south one moves (the farther away from the equator), the colder the weather becomes.

TEACHER TAKE NOTE

The term *upwelling* refers to the flow of cold, deep waters to the surface, in apparent contradiction to the natural law that cold, dense waters sink and warmer, less dense waters rise. Pedestal upwelling of this type is usually not mentioned in standard texts, which use the term *upwelling* mainly in connection with the seasonal overturn of lakes in cold climates. The upwelling seen in the Galápagos is caused by an offshore current that carries water away from the coast, creating, in effect, a valley in the ocean's surface. Cold, deeper waters flow into the valley.

The upwelling brings rich nutrients to the islands. In January, a snorkeler or scuba diver would find nearshore waters to be about 20°C. Direct students to lightly shade the warm (25°C) current red and the cold (18-19°C) current blue, then decide how to color-code the 20°C nearshore water.

8. Direct students' attention to the diagram for May on the transparency of Master 3.4e, Currents and Upwellings. Point out that the warm current from the north is stronger in this month, so that the cold upwelling does not reach the surface. Warm water that is relatively poor in nutrients surrounds the islands. A snorkeler or scuba diver would find the water to be about 25°C. The robot JJ, however, could dive deep enough to reach the cold upwelling water.

9. Indicate October on the transparency made from Master 3.4e, Currents and Upwellings. In this month the predominant current is from the south, carrying cool water (20 to 22°C) toward the island, and the upwelling is at its strongest. Both a scuba diver and a deeper-diving submersible would encounter cold currents around the island, bringing water at about 18-19°C. The water would be nutrient-rich, so marine plants (algae) would flourish.

C. Conclusion

Review the significance of the diagram on Master 3.4e. Currents bring water of varying temperatures and nutrient levels to the Galápagos Islands. Warm currents cause more water to evaporate from the ocean, so there is more rain; cold currents mean less evaporation and less rain. Cold currents bring nutrient-rich water which allows an abundance of life to thrive. If the currents are warm, the water is relatively nutrient-poor, so life forms are less abundant. Build a class discussion around these questions:

- Which month is probably the warmest and wettest in the Galápagos? (May, when the islands are surrounded by warm water)

- Which is the coldest and driest? (October, when the islands are surrounded by cold water)

- If tropical organisms like butterflyfish thrive in warm water, when would we be most likely to find them in the waters surrounding the Galápagos? (May, in the warm surface waters)

- During what season or month of the year would we most likely find temperate zone organisms in the coastal waters? (the dry season, or October)

- Predict what kinds of organisms the JASON expedition's scuba diver and the robot JJ will find in the coastal waters in December. Use the terms *tropical organisms* and *temperate-zone organisms*. Give reasons for your predictions.

ACTIVITY FOUR

Sea Surface Temperatures

Rationale

Satellites routinely record sea surface temperatures (SST) and relay this information to ground stations. The stations generate false color maps that indicate SST at a glance. Oceanographers map temperature zones by drawing lines on the maps, called *isotherms*, to connect areas of the same temperature. Changes of a few degrees in a region's SST can signal the beginning of an El Niño event. In this activity students will simulate the false color coding of an SST map.

Objectives

Students will:

Color-code maps to show SST changes during El Niño.

Compare sea surface temperatures before and during an El Niño event.

Materials

- Transparency made from Master 3.4f, Sea Surface Temperatures, May 1982
- Overhead projector
- Student copies of Master 3.4f, Sea Surface Temperatures, May 1982
- Transparency made from Master 3.4g, Sea Surface Temperatures, May 1983
- Student copies of Master 3.4g, Sea Surface Temperatures, May 1983
- Colored pencils or crayons in six colors

Procedure

A. Introduction

Project the transparency made from Master 3.4f, Sea Surface Temperatures, May 1982. Explain to students that oceanographers study sea surface temperatures to determine if an El Niño or other unusual event is taking place. The colors on SST maps indicate temperature differences of the surface water. In this activity students will make colored maps of the ocean surface water for two consecutive years.

B. Procedure

1. Pass out student copies of Master 3.4f, Sea Surface Temperatures, May 1982.

2. Orient the students. Be sure they understand they are looking at a map of the Pacific Ocean. Ask for volunteers to locate the Galápagos Islands and Ecuador on the South American continent.

3. Remind students that during May the water temperature around the Galápagos is at its warmest. Direct their attention to the Galápagos Islands in the May 1982 map, and point out that the water is about 25°C.

Ask the students to find the warmest area on the map and color it red. Code the other temperatures by using the colors indicated on the map.

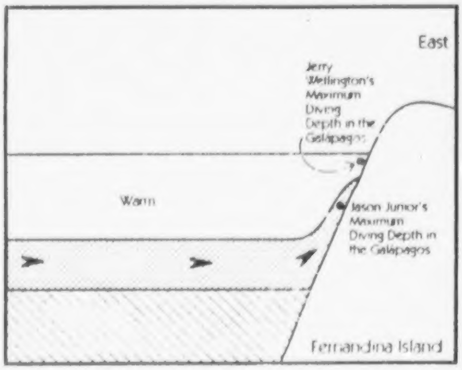
VOCABULARY

False col•or map - a map that uses colors to represent differences other than color.

I•so•therm - a line connecting areas of equal temperature.

Sea sur•face tem•per•a• ture (SST) - a standard measurement of the average surface temperatures of ocean water.

May


East
Jerry Wellington's Maximum Diving Depth in the Galápagos
Warm
Jason Junior's Maximum Diving Depth in the Galápagos
Fernandina Island

TEACHER TAKE NOTE

Explain that the numbers on the map indicate relative temperatures, not actual temperatures. The lowest temperature is 0 and the highest is 5.

4. When students have finished, project the transparency made from Master 3.4g, Sea Surface Temperatures, May 1983, and pass out student copies. Tell students that the actual water temperature around the Galápagos at this time was around 30°C. Have students color in the map as before.

5. Ask students to compare the two maps they colored and describe the differences. Explain that the May 1983 map shows an El Niño event. Water temperatures in the ocean have changed several degrees, a significant shift. Invite students to hypothesize on the effect of this increase on the weather in the Galápagos. (Higher temperatures raise the level of the ocean waters, bringing high waves and storms that are more severe than usual.)

C. Conclusion

Review the main points from the earlier activities in this lesson to help students put the maps in context. The weather and climate of the Galápagos Islands are determined largely by the ocean waters that surround them. When the surrounding water is warm, the Galápagos weather is warm and wet. When the surrounding water is cold, the Galápagos weather is cool and dry. Most of the time, these seasonal patterns are regular. Periodically, though, a severe disturbance occurs. Use these questions to conclude the review:

- What changed between 1982 and 1983? (The water temperature in the Galápagos rose to 30°C during an El Niño. Other ocean areas also grew warmer.)

- How can comparing the water conditions shown in the two maps help scientists? (Answers will vary. Students should realize, though, that warnings can be issued if a temperature shift is detected in time.)

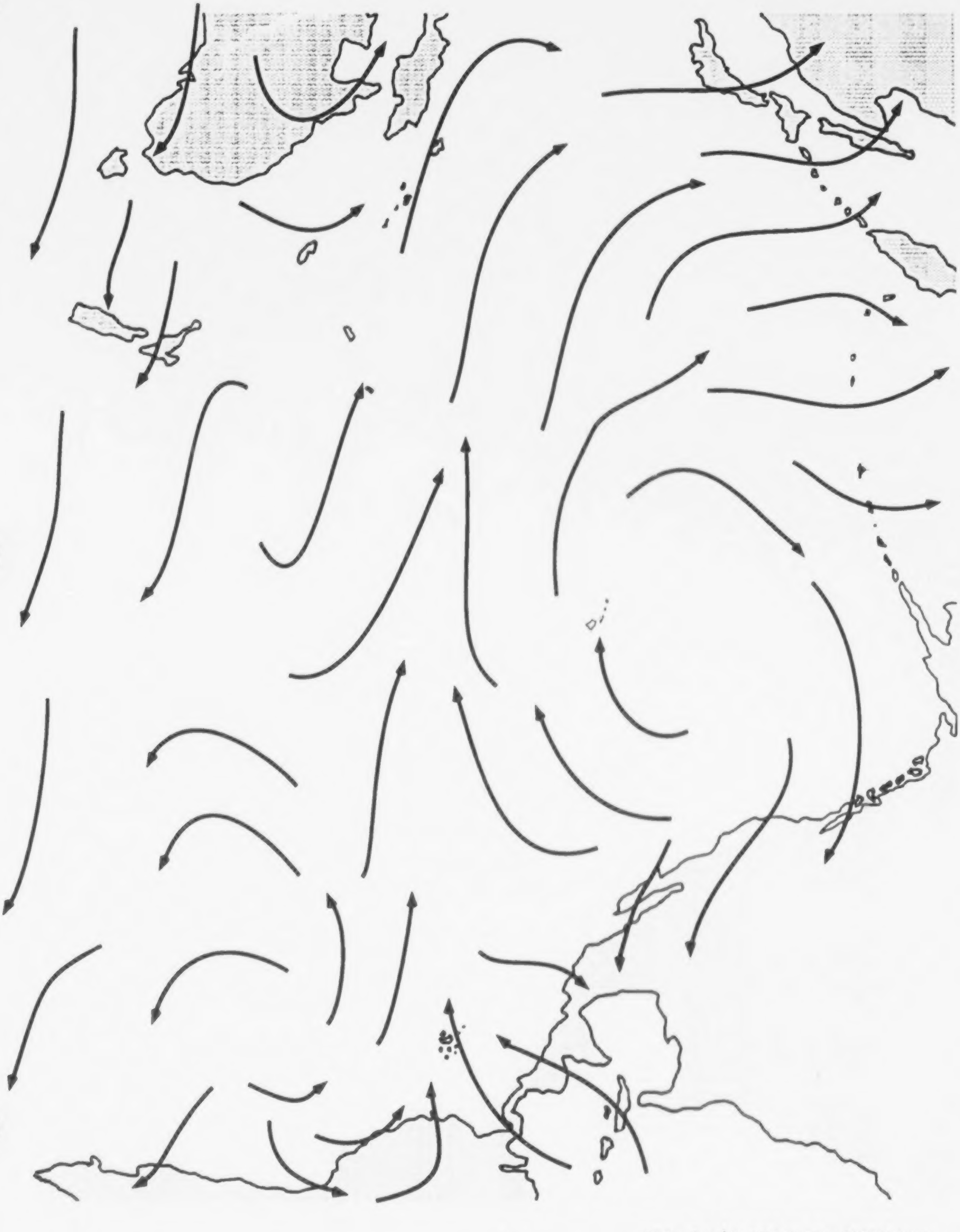
- How are ocean water conditions during an El Niño different from those normally expected during May? (The ocean water around the Galápagos is considerably warmer, about 30°C rather than 25°C. Large areas of the Eastern Pacific Ocean are also considerably warmer.)

- How is an El Niño likely to affect the weather in the Galápagos Islands? (Rainstorms become more severe and rainfall is heavier than normal. Normally dry areas receive much rain. Runoff causes some coastal flooding, gushing fresh water into shallow coastal areas. Ocean waves are larger, and these pound on the coasts.)

- If the El Niño lasted for several months, how would it affect the plants and animals living on the islands and in the coastal waters? (More rain on the islands would mean more plant growth. With more plant life for food, animals on the islands would prosper. Coastal marine life would not do as well, partially because coastal areas would be flooded with runoff and fresh water that is harmful to algae. The warmer currents would also carry less nutrients for algae.)

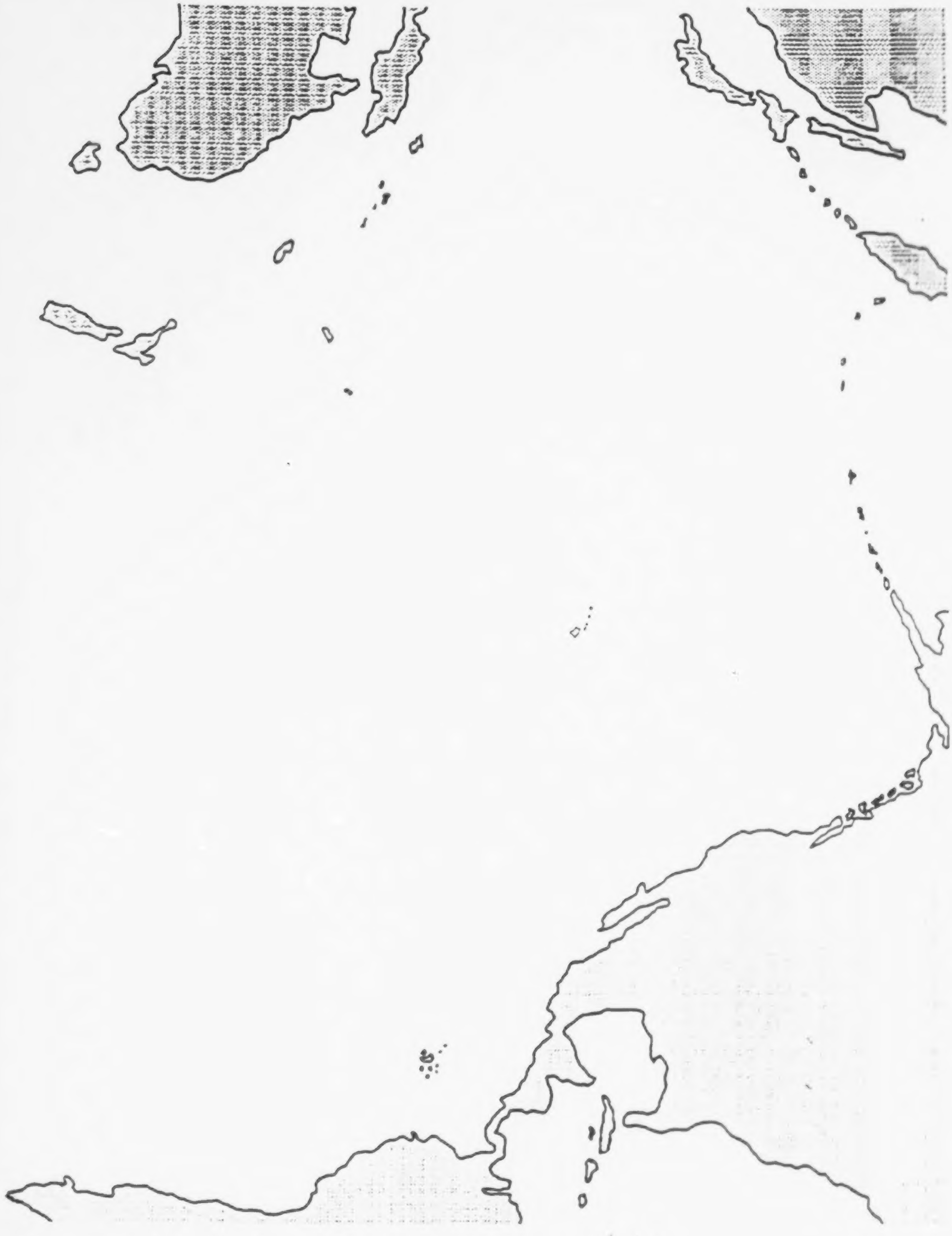
Prevailing Winds of the Equatorial Pacific

MASTER
3.4a



MASTER 3.4b

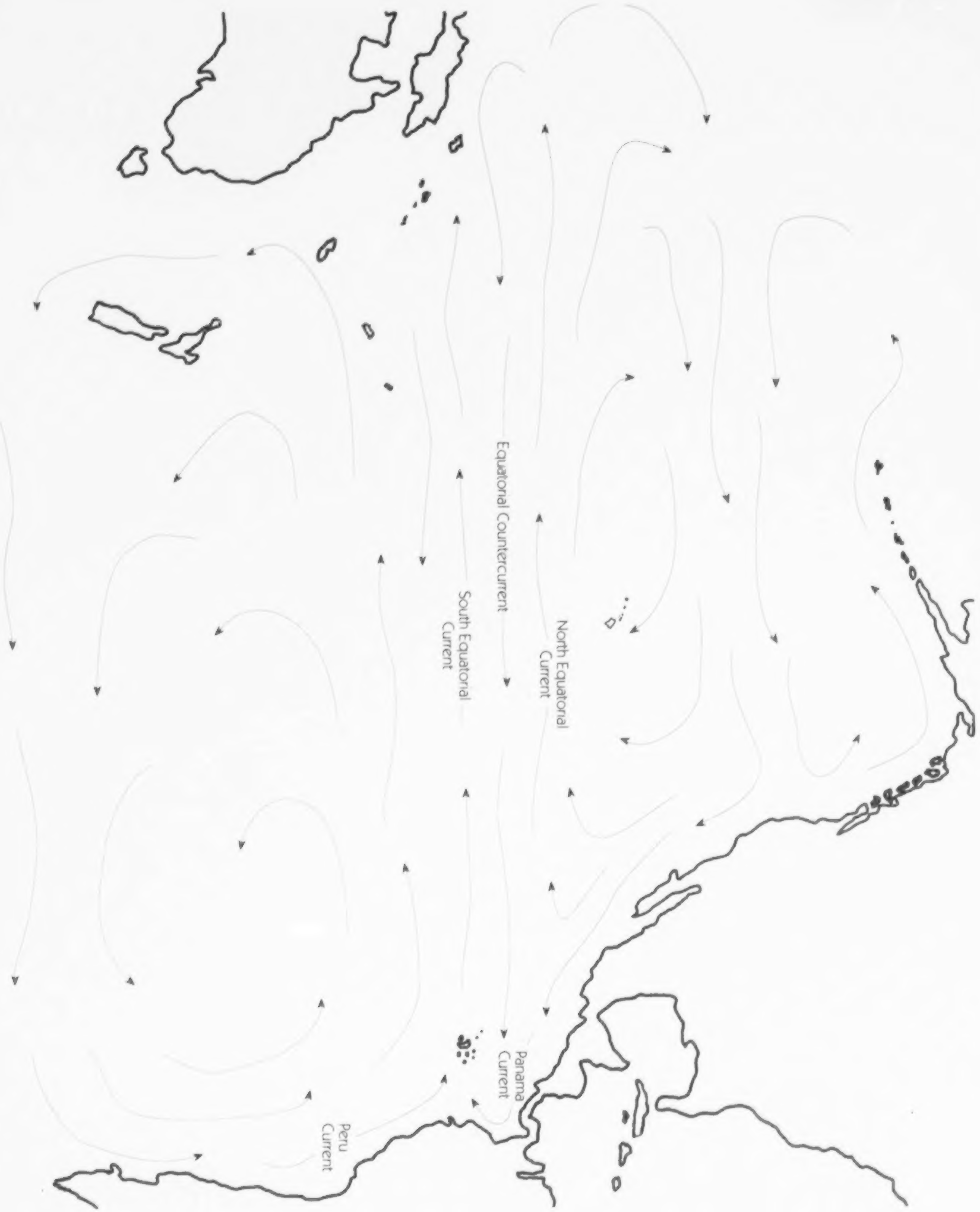
Map of the Equatorial Pacific



170

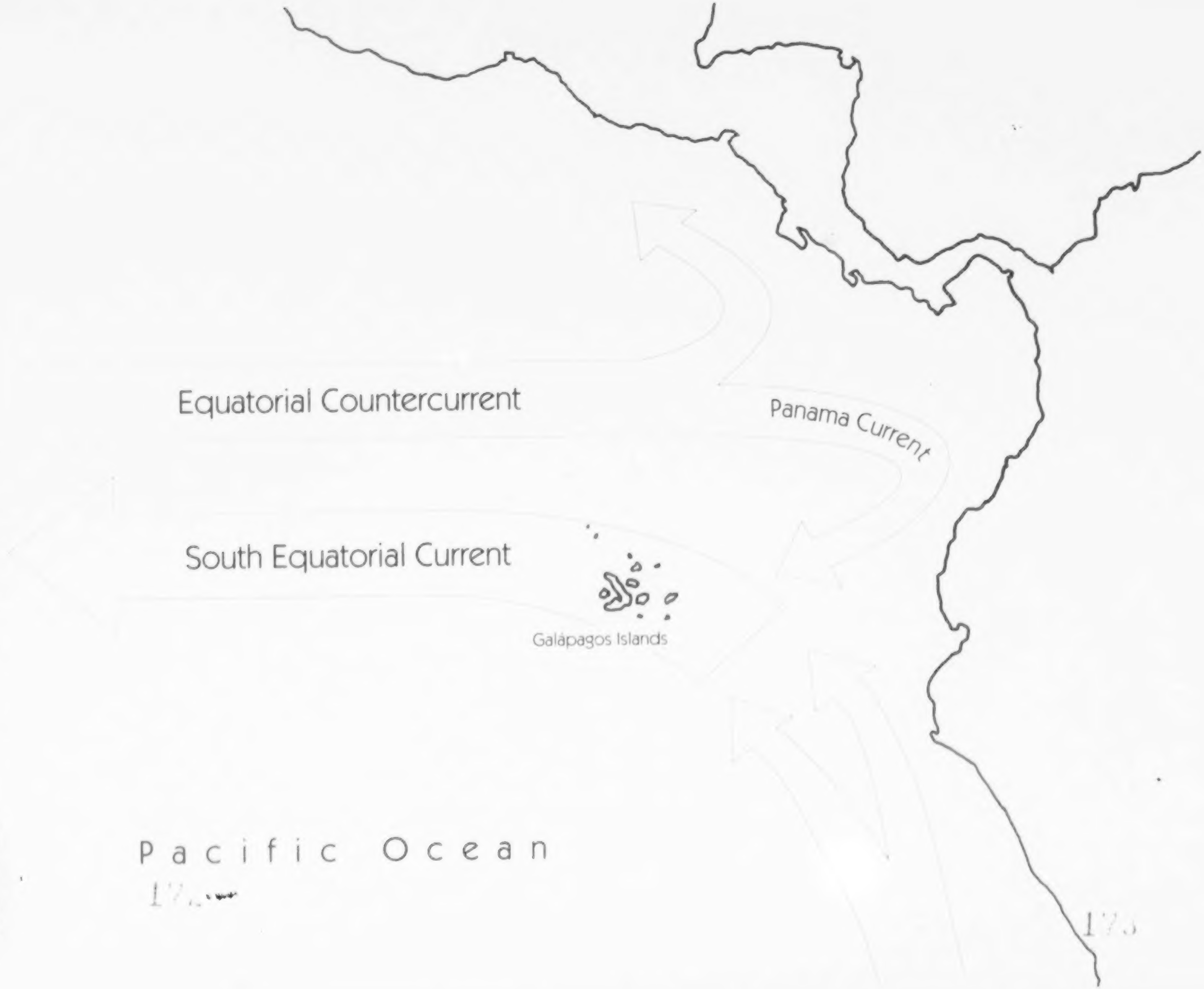
Equatorial Pacific Currents

MASTER
3.4c


Equatorial Countercurrent
South Equatorial Current
North Equatorial Current
Panama Current
Peru Current

MASTER
3.4d

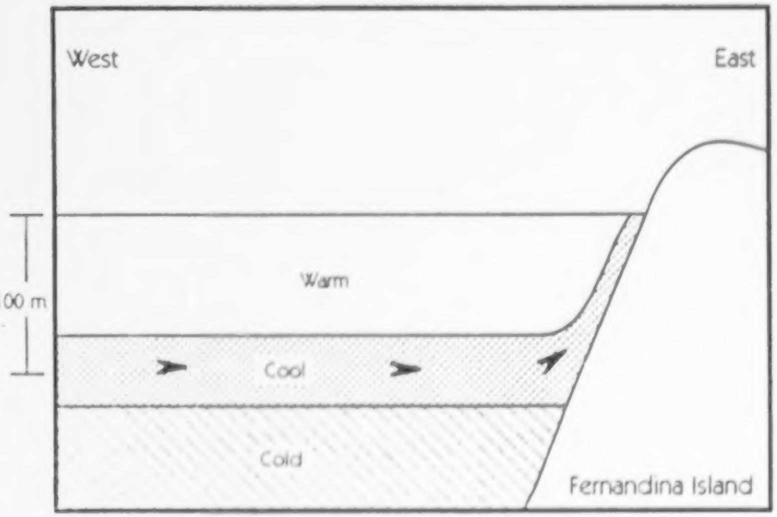
Currents in the Galápagos Area


Equatorial Countercurrent
Panama Current
South Equatorial Current
Galápagos Islands
Pacific Ocean

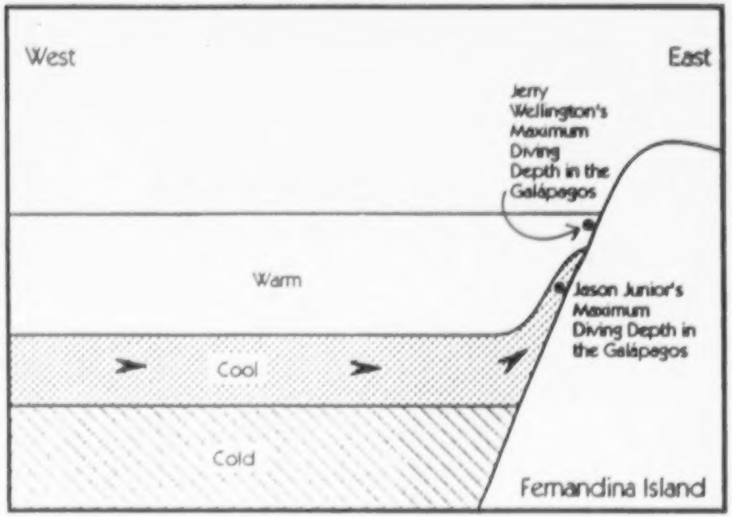
MASTER 3.4e

Currents and Upwellings

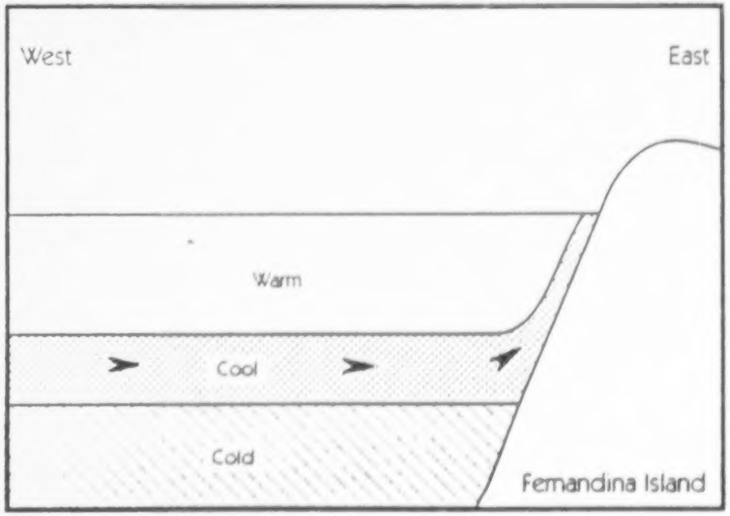
January


West
East
100 m
Warm
Cool
Cold
Fernandina Island

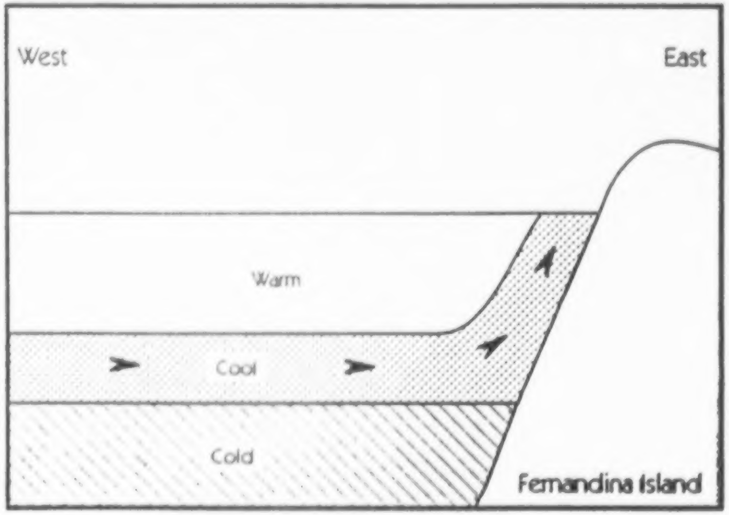
May


West
East
Jerry Wellington's Maximum Diving Depth in the Galápagos
Warm
Jason Junior's Maximum Diving Depth in the Galápagos
Cool
Cold
Fernandina Island

June (Same as January)

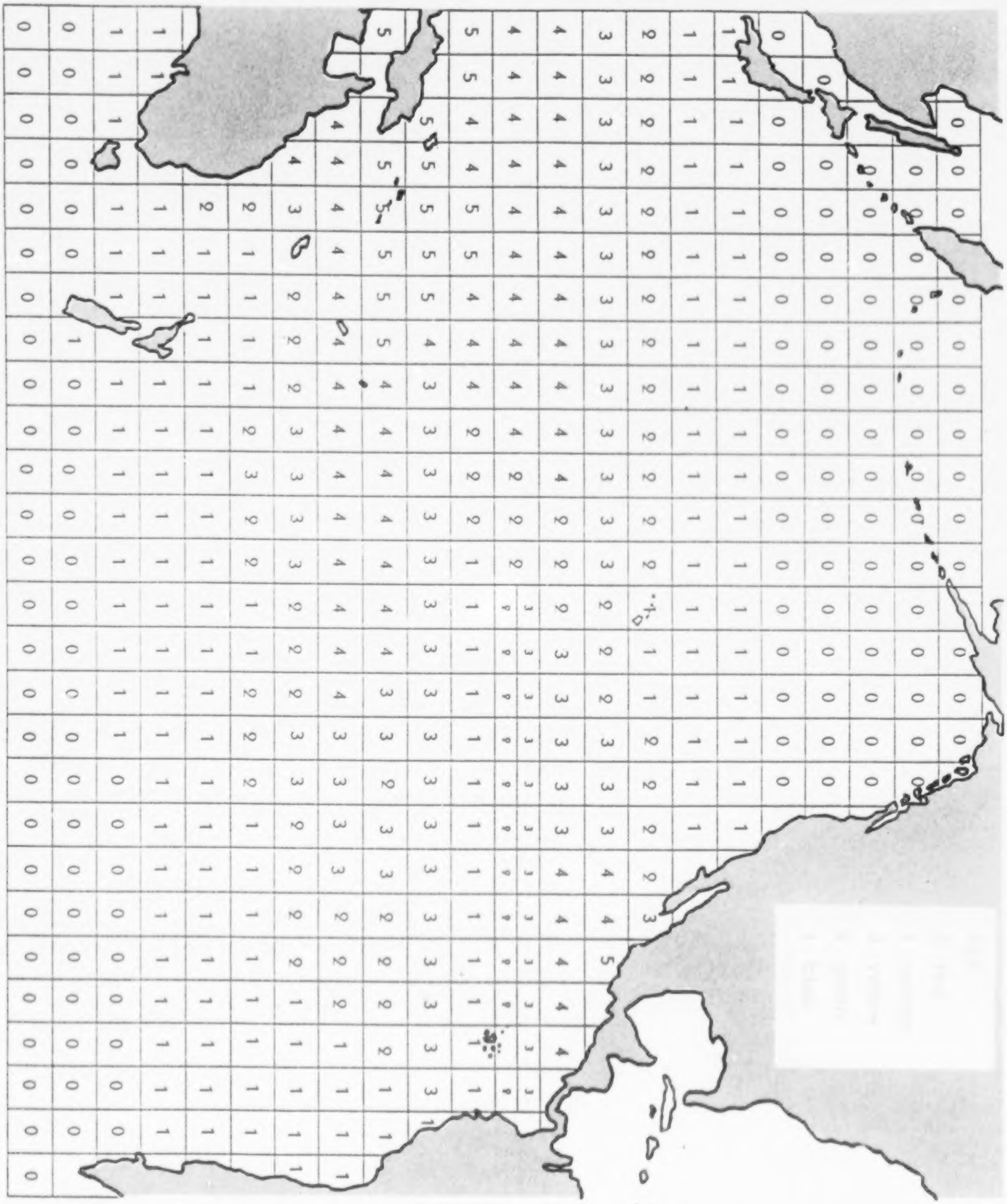

West
East
Warm
Cool
Cold
Fernandina Island

October

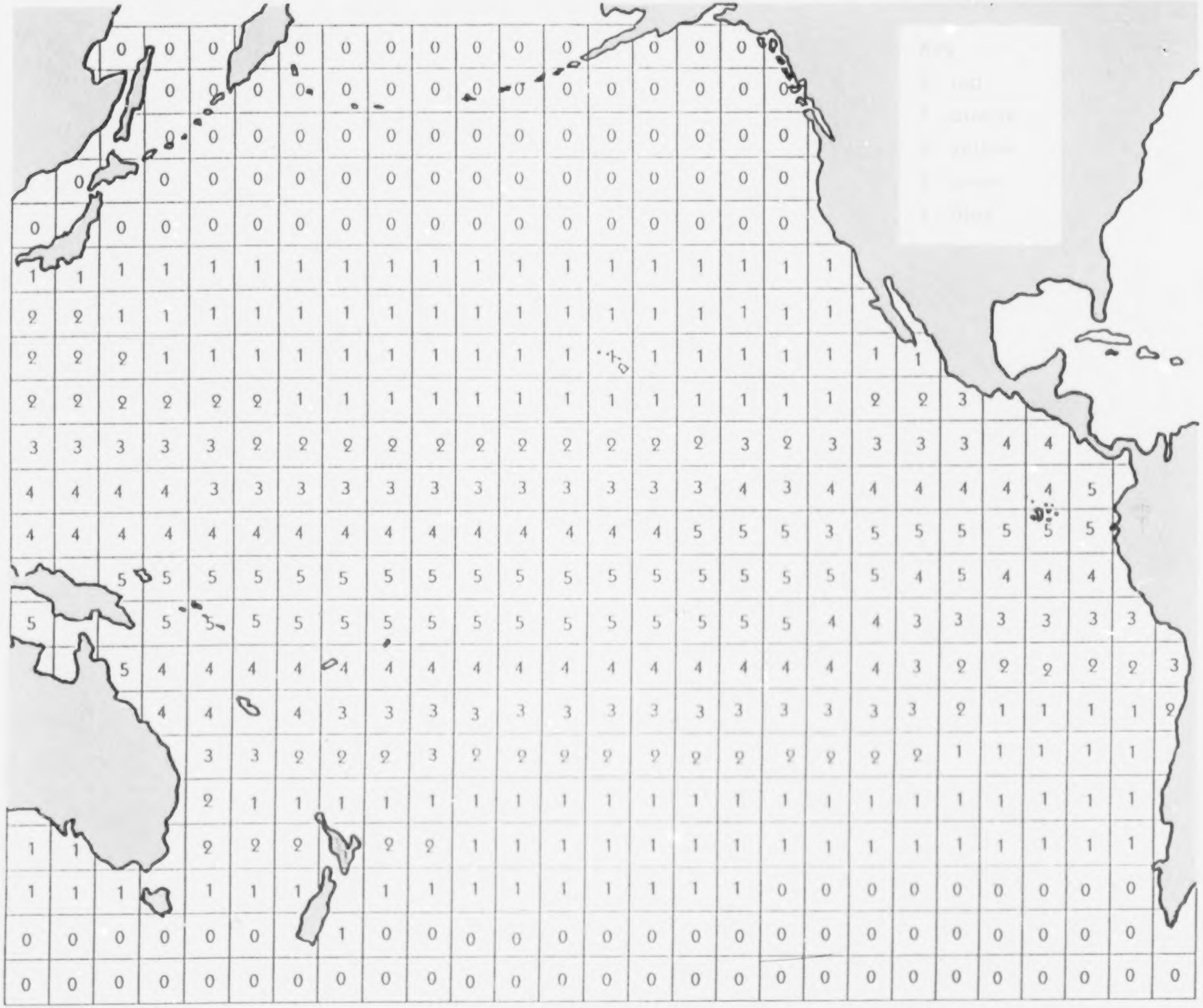

West
East
Warm
Cool
Cold
Fernandina Island

MASTER 3.4f

Sea Surface Temperatures, May 1982



Sea Surface Temperatures, May 1983



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0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0									
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
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THE BIODIVERSITY OF THE GALÁPAGOS ISLANDS

3.5

ACTIVITY ONE

Climate and Vegetation

Rationale

Photosynthetic organisms are the basis of every terrestrial food chain. This activity points up the dependence of vegetation on climatic conditions and the dependence of other creatures on the vegetation.

Objectives

Students will:

Review the water cycle.

Assign plant species to their respective places on a model of rainfall zones.

Name the major vegetative zones of the Galápagos Islands.

Form hypotheses about the effects of climate change on these zones and the species that inhabit them.

Materials

- Overhead projector
- Transparency made from Master 1.2b, Galápagos Map (*optional*)
- Transparency made from Master 3.5a, Vegetative Zones of a Galápagos Island
- Student copies of Master 3.5a, Vegetative Zones of a Galápagos Island
- Student copies of Master 3.5b, Plant Species of the Galápagos (two sides)

Procedure

Teacher Preparation

If you have not done any of the activities in Lesson 3.2 with your class, read them over now so you will be prepared to describe the volcanic origin of the Galápagos.

A. Introduction

If your class needs a review, project the map of the Galápagos Islands and point out their location, 1000 km (600 miles) from the coast of Ecuador. Briefly describe their volcanic origin and their physical characteristics. Project Master 3.5a, Vegetative Zones, and point to it as you review the water cycle (see illustration on the next page). Explain that in the Galápagos, even though rain may be infrequent, the cooling

VOCABULARY

A•dap•ta•tion - change as a result of adjustment to environmental conditions.

Mu•tu•al•is•tic - describes a relationship between two organisms in which each derives something of benefit.

Pin•ni•ped - the suborder of meat-eating aquatic mammals that includes the seals and walruses.

Prop roots - roots that extend from the branches to the ground, forming a support for the growing plant.

Wind•ward - the direction from which the wind is blowing.

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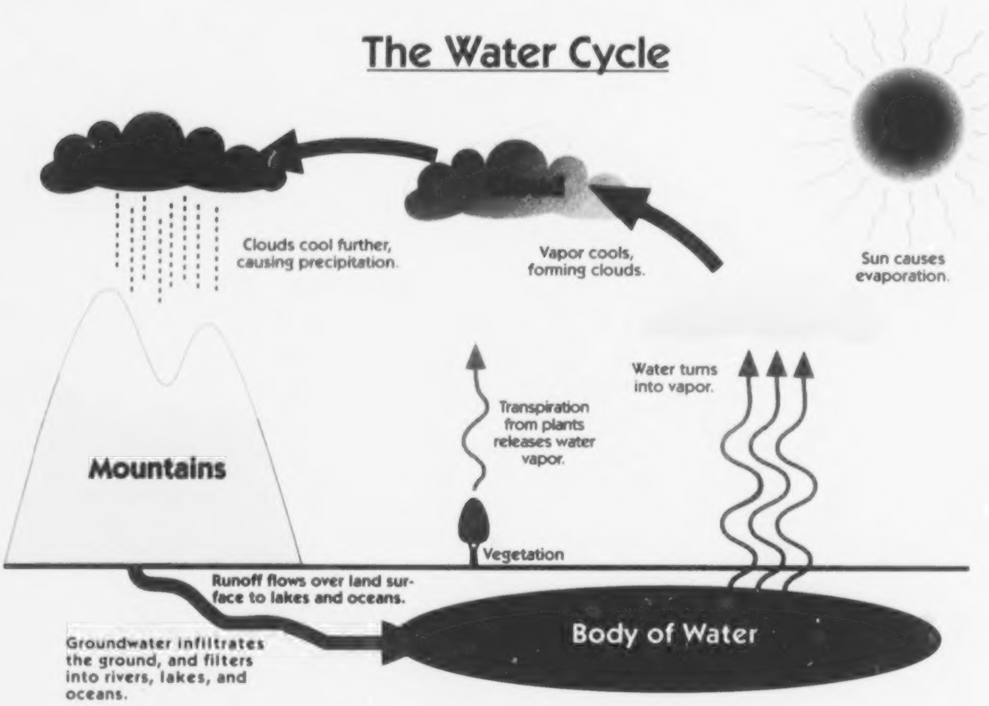
of rising moist air results in misty precipitation high on the windward side of the mountains/islands. Different types of plant life adapt to different niches on a volcanic island.

The Water Cycle


Clouds cool further, causing precipitation.
Vapor cools, forming clouds.
Sun causes evaporation.
Water turns into vapor.
Transpiration from plants releases water vapor.
Mountains
Vegetation
Runoff flows over land surface to lakes and oceans.
Groundwater infiltrates the ground, and filters into rivers, lakes, and oceans.
Body of Water

TEACHER TAKE NOTE

Do not collect the vegetative zone masters (Master 3.5a). Instruct students to keep them in their JASON journals. They will also be used in Activity Three of this lesson.

B. Lesson Development

1. Ask your students to imagine a volcanic island newly risen from the sea, about four million years ago. How would it look? (bare, rugged, and sterile) Ask:

- How did vegetation arrive on the Galápagos Islands? (We don't know for certain, but we assume seeds were blown, floated, or transported by animals from the mainland.)

- What conditions do plants need to grow? (All plants need moisture and nourishment, and most need light. Plants vary greatly in their individual requirements, however.)

- What growing conditions exist in the Galápagos? (Soil is thin and relatively devoid of nutrients. Rainfall is scant during most of the year. Students will probably not yet be aware of the better growing conditions in the highlands.)

- Would you expect to find a wide variety of plants in these islands? (No.)

2. Distribute student copies of Master 3.5a, Vegetative Zones of a Galápagos Island, and Master 3.5b, Plant Species of the Galápagos. Give students time to read the material and use the key to fill in symbols on Master 3.5a for the types of vegetation that might occur in each zone.

3. Divide students into pairs or teams to compare their diagrams and discuss the reasons for any variations. Also discuss the changes that might occur in each region during exceptionally dry weather or exceptionally warm, wet weather, as in an El Niño year.

C. Conclusion

Ask one student in each team to name one of the six vegetative zones and describe it briefly. Discuss:

- What factors seem to be most important in determining the type of vegetation in each zone? (the amount and type of moisture available)

- What effect would a 10° rise in temperature have on the vegetation of each zone? (Refer back to the activities in Lesson 3.4.)

- If an island has an elevation of 500 meters (1,644 feet), what kind of vegetation will grow in its top zone? (humid area plants)

Adaptations

For younger students

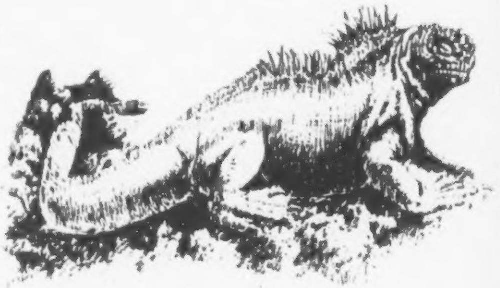
1. Sketch a larger version of Master 3.5a on poster board. Have students draw plants in the appropriate areas, or cut and paste the pictures from Master 3.5b. Keep the poster to use in Activity Three.

2. Over a period of three weeks in the classroom, compare the effects of dry, moist, and soggy wet conditions on three plants of the same type. (Try African violets, geraniums, or grass.) Observe and keep a data chart. At the end of the experiment, decide which environment seems to be best for the plant.

For older students

Set up three terrariums in large glass jars or in cut-off one-liter plastic bottles. Put the same variety of plants in each one, making the three as much alike as possible. Expose one to dry, one to moist, and one to soggy wet conditions. Compare what you observe to the zonation of plants in nature.

ACTIVITY TWO
Galápagos Iguanas



Rationale

Scientists need skills in observing, forming hypotheses, and gathering data to test their hypotheses. Students can develop observation skills by comparing pictures of and information about related species.

Objectives

Students will:

- Carefully observe drawings of the marine and land iguanas found in the Galápagos.

List the differences they notice.

Formulate hypotheses about how these differences allow each to live in its particular habitat.

Compare other land animals and discuss their adaptations.

- Student copies of Master 3.5c, Marine and Land Iguanas, one for every two students
- Student copies of Master 3.5d, Iguana Worksheet, one for every two students
- Back of Master 3.5d, Teacher Key to Iguana Worksheet
- Student copies of Master 3.5e, Some Animals of the Galápagos Islands (both sides)
- Student copies of Master 3.5f, Compare and Contrast Worksheet

Procedure

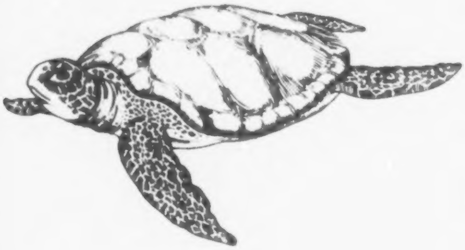
A. Introduction

Explain: Random changes occur in the individuals of every species from one generation to another. Some of these changes adapt certain individuals of the species to survive in particular environments. Such changes may lead to the development of two distinct animals with very different lifestyles, such as land and marine iguanas.

B. Lesson Development

1. Direct students to work in pairs. Distribute copies of Master 3.5c and Master 3.5d, the drawings and the worksheet. Tell students to assume that the two drawings depict males of equal size.

2. Instruct students to compare the two drawings carefully and list any differences they notice on the lines marked *observation*. Urge them to list all the differences they notice, no matter how small. Even a tiny piece of data may turn out to be important.



3. When the lists are complete, have all the students hypothesize together about why these closely related animals have evolved in such different ways. How do these adaptations allow each iguana to thrive in its particular niche?

4. Hand out copies of Master 3.5e, Some Animals of the Galápagos Islands, and Master 3.5f, Compare and Contrast Worksheet.

Explain that through the process of natural selection, other Galápagos animals have also developed specific adaptations. Eleven subspecies of tortoise, for example, have developed to fill specific niches in the ecosystem. Charles Darwin's observation of the many subspecies of finches was one of the keys that led him to develop his theory of the origin of species.

5. Rearrange the class into groups of five. Within the groups, each student will choose a pair or set of animals to compare and contrast, such as:

- land iguanas and marine iguanas
- turtles and tortoises
- flightless cormorants and penguins
- blue footed, red footed, and masked boobies
- fur seals and sea lions

6. Have students use the information in the text and the pictures on Master 3.5e to individually answer the questions on Master 3.5f, comparing and contrasting the animals they selected.

7. When all students have finished filling out the second worksheet, ask them to share what they have learned with the other students in their group. Allow a few moments for the class as a whole to compare information and reach consensus on any areas of disagreement.

C. Conclusion

Discuss: How have isolation and the unique conditions existing on these islands given rise to the unusual features of Galápagos animals? Ask students to give examples of features from the animals they compared. (The organisms of the Galápagos have been stranded in an area that is harsh in many ways, but also offers some advantages. The animals living there have been able to adapt to specific niches in the ecosystem. Due to the upwelling of cool, nutrient-rich waters, there is an abundance of food not normally found in tropical waters. Temperatures on land tend to be cooler than elsewhere in the tropics because of the cool water temperatures. And until recently, the islands' natural isolation prevented most predators from establishing significant numbers.)

Do not collect the worksheets. Explain to the class that observation and hypothesis are only part of a scientist's work. The scientist must also test each hypothesis to see if it is verifiable. Since some of these animals will be visible during the JASON transmission, the students may gather data to test their hypotheses by observing animal behavior in the natural habitats. Instruct students to keep the worksheets in their JASON journals.

TEACHER TAKE NOTE

Be sure students understand that they will not observe all the different behaviors of the animals during the transmission. Scientific observation requires long, patient waiting, and their time for viewing will be strictly limited.

Expedition Review

Remind students to take their JASON journals to the museum and record any new observations on the data sheets.

Adaptation

For all ages

Explain that the length of time a scientist has to make observations of an animal on any one occasion is limited by weather, light, unpredictable animal behaviors, and other factors. Set a time limit of one minute for looking at the pictures on Master 3.5c, then remove the pictures and see how well students can record the differences from memory.

ACTIVITY THREE

Land Animal Diversity in the Galápagos

Rationale

A wide variety of life forms has been able to survive in the Galápagos Islands. Some are like those found elsewhere, but many are truly unique to the Galápagos ecosystem.

Objectives

Students will:

Match animals with the appropriate life zones and discuss why the animals are found in these zones.

Observe some of the characteristics of animals found in the Galápagos.

Relate specific organisms to specific habitats within the archipelago.

TEACHER TAKE NOTE

If students will use Master 3.5a for this activity, reduce the copies of 3.5e before distributing them. If the class made a poster in Activity One, they can use it again for this activity instead of Master 3.5a.

Materials

- Poster included with this curriculum
- Student copies of Master 3.5e, Some Animals of the Galápagos Islands (two sides)
- Student copies of Master 3.5a, Vegetative Zones of the Galápagos Islands (saved from Activity One)
- Pencils or pens
- Scissors
- Transparent tape
- Paper plates; scissors; string or rubber bands; black, red and blue wide markers (*optional*, for younger students adaptation)
- Student copies of Master 3.5g, More Land Animals (*optional*, for older students adaptation)

Procedure

A. Introduction

Display the poster that accompanies this curriculum and ask students to identify all the animals they recognize, as well as the environment in which each is pictured. Hang the poster in a spot where all the students can see it.

B. Lesson Development

1. Have students remain in their work groups of five from Activity Two. Ask them to turn over their individual copies of Master 3.5e and write the name of each animal on the back of its picture, so they will be able to identify it later. Next ask them to cut out the animal pictures on the master. As they work, have them compare the drawings on the master with those on the poster.

2. Instruct students to take out their copies of Master 3.5a, Vegetative Zones of the Galápagos, and add the title *Animal Life Zones*. Working together, they can decide where to place

each animal, then glue or tape the reduced pictures in areas where animals might be found feeding or nesting at various times of the day.

3. Compare the results from the various groups and discuss similarities and differences.

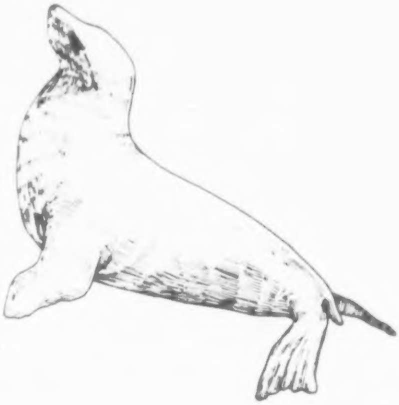
C. Conclusion

Discuss the following questions:

- What conditions might exist in the Galápagos in the year 2990? (Students may be aware of global warming and other such trends, and draw on this knowledge in making their predictions.)

- Imagine a land animal that would survive the conditions you project for the Galápagos in the year 2990. What characteristics would it have?

- How would it be similar to or different from those already living on the Galápagos Islands? (more adaptations—some perhaps resulting from increased human visitation—leading to greater specialization, new subspecies)



Adaptations

For younger students

1. Display Master 3.5e, Some Animals of the Galápagos Islands, and point out the three types of boobies. Write the words to the Booby Bird Bop (see next page) on the chalkboard. Provide students with paper plates; scissors; string or rubber bands; and black, red, and blue wide markers. Divide the students into three groups, one representing blue-footed boobies, one representing red-footed boobies, and one representing masked boobies. Have them use the plates to make blue and red feet and black masks, then attach the plates to the tops of their feet or their faces with string or rubber bands. Gather students into a large circle, then follow the directions in the song.

2. Challenge students to draw imaginary animals that might result from changing conditions in the Galápagos over the next hundred years, and be able to explain each adaptation.

For older students

1. Lead into a discussion of how these Galápagos animals would have to adapt to survive in other parts of the world.

2. Expand to discuss other organisms found in the Galápagos. (See supplementary list on Master 3.5g, More Land Animals, and the masters from Lesson 3.7.)

For all ages

Challenge students to gather pictures of other animal pairs from magazines and repeat Activity Three. Some examples could be: draft horse vs. race horse, penguin vs. hawk, or bloodhound vs. labrador retriever.

Booby Bird Bop

(Sung to the tune of "The Hokey Pokey")

(all together in a circle)
You put your right foot in,
You take your right foot out.
You put your right foot in,
And you shake it all about.
You do the Booby Bop
And you waddle all around:
That's what it's all about.

(blue feet only)
You put your blue foot in,
You take your blue foot out.
You put your blue foot in,
And you shake it all about.
You do the Booby Bop
And you waddle all around:
That's what it's all about.

(red feet only)
You put your red foot in,
You take your red foot out.
You put your red foot in,
And you shake it all about.
You do the Booby Bop
And you waddle all around:
That's what it's all about.

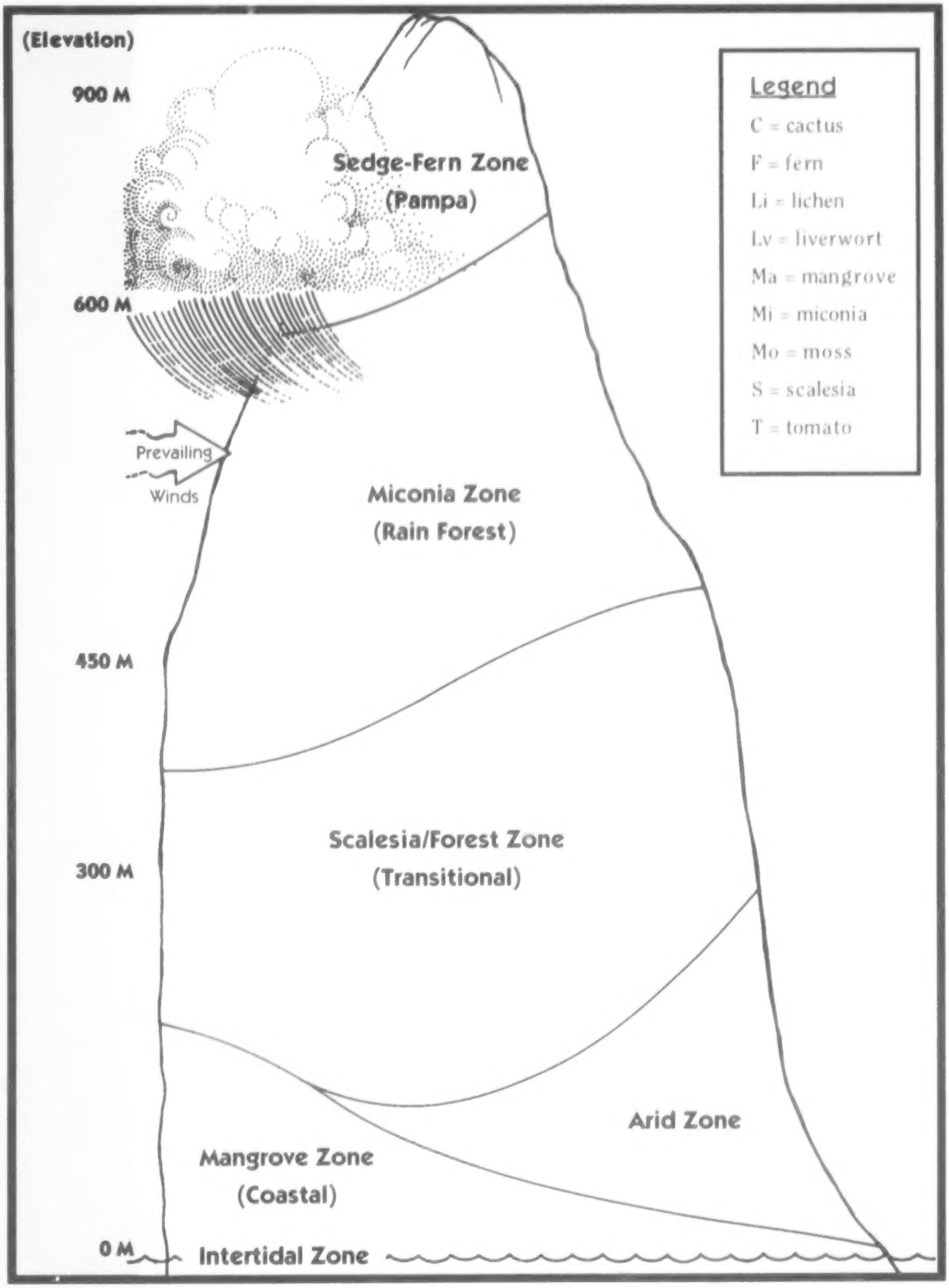
(masked faces only)
You put your masked face in,
You take your masked face out.
You put your masked face in,
And you shake it all about.
You do the Booby Bop
And you waddle all around:
That's what it's all about.

(all together)
You do the Booby Bop,
Like those birds in the Galápagos! You do the Booby Bop,
And you shake yourself about.
You do the Booby Bop
And you waddle all around:
That's what it's all about.

Vegetative Zones of a Galápagos Island

MASTER
3.5a

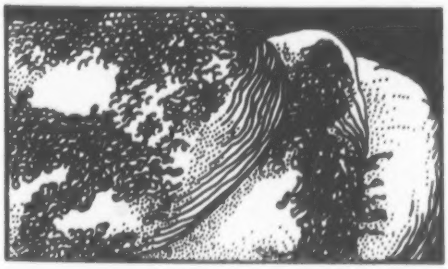
Directions: *Draw each plant in the area where it is most likely to occur, and mark the symbol for its name. You may use symbols more than once. Save this master to use in another activity.*


(Elevation)
900 M
600 M
450 M
300 M
0 M
Prevailing
Winds
Sedge-Fern Zone
(Pampa)
Miconia Zone
(Rain Forest)
Scalesia/Forest Zone
(Transitional)
Arid Zone
Mangrove Zone
(Coastal)
Intertidal Zone
Legend
C = cactus
F = fern
Li = lichen
Lv = liverwort
Ma = mangrove
Mi = miconia
Mo = moss
S = scalesia
T = tomato

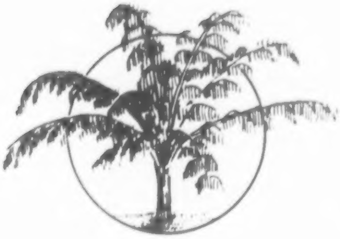
Plant Species of the Galápagos

All Zones

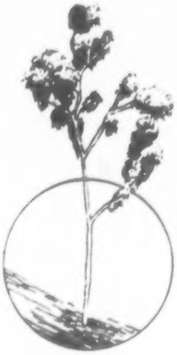
Lichens - Lichens are found in all of the vegetative zones, since they are not dependent on soil. Each plant is made of an alga and a fungus. This mutualistic relationship supplies the needs of both organisms.



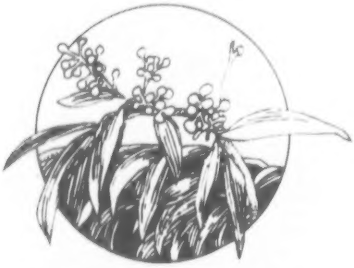
Highlands: Humid Area Plants
(Grow in Sedge-Fern, Miconia, and Scalesia/Forest Zones)



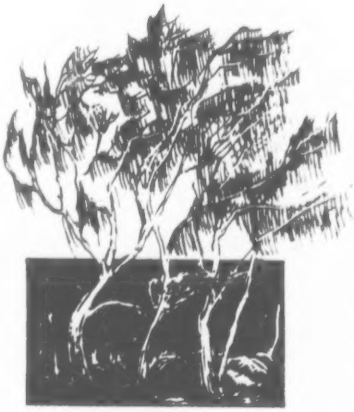
Sedge-Ferns - Ninety different species grow in the islands, some as large as 3 m tall (almost 10 ft). They reproduce by spores, which can travel great distances. They grow in the Scalesia/Forest and Miconia Zones.



Scalesia - This is the tallest member of the daisy family. Trees with white flowers grow up to 15 m (49 ft). Scalesia thrives in dense rain forest settings. It is the dominant plant in the Scalesia/Forest Zone.



Miconia - This flowering shrub grows from 2–5 m tall (6.5–16 ft). Its green leaves turn red-orange during the dry season. Clusters of flowers grow at the tips of the branches. Its fruit is a blue-black berry. It is the dominant plant in the Miconia Zone.



Tree covered with mosses and liverworts

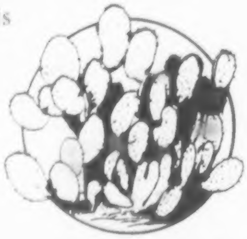
Mosses - There are also about 90 species of moss in the Galápagos. They are found in all humid zones, but predominantly in the Scalesia /Forest Zone.

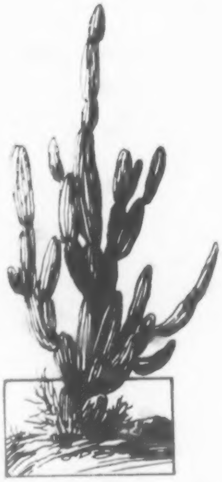
Liverworts - About 110 species of liverworts occur in the islands. They are found predominantly in the Miconia Zone.

Back of Master 3.5b
Plant Species of the Galápagos

Arid Zone: Dry Area Plants

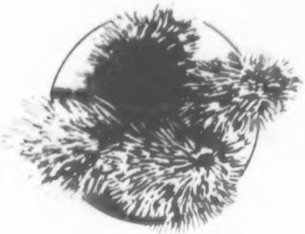
Prickly Pear Cactus - This cactus grows up to 12 m (over 39 ft) with a thick trunk, flat pads, spines, yellow flowers and greenish fruit.

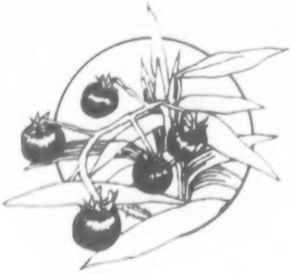




Candelabra Cactus - This species grows to about 7 m high (23 ft). Its branches look like organ pipes or like the arms of a giant candelabra.

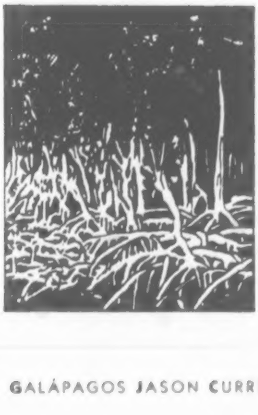
Lava Cactus - This is a short, thick cactus only about 12 cm (5 in.) high. Each branch is covered with many spines, and lasts only a few years. Its flowers open before dawn, and shrivel by 7 or 8 a.m.





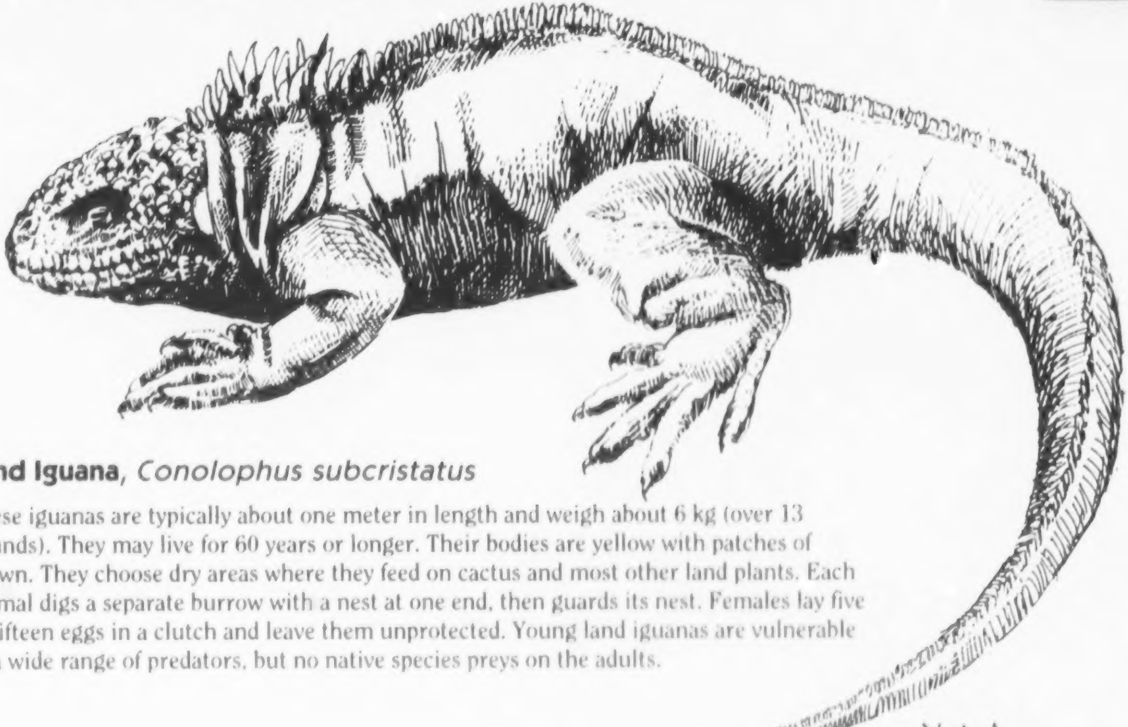
Galápagos Tomato - This variety of tomato is a small plant with spear-shaped leaves and small yellow or red fruit. Its seeds have evolved a thick coat to resist salt and drying. They usually sprout only after passing through the intestines of a tortoise or a mockingbird.

Mangrove Zone: Salt Resistant Plant



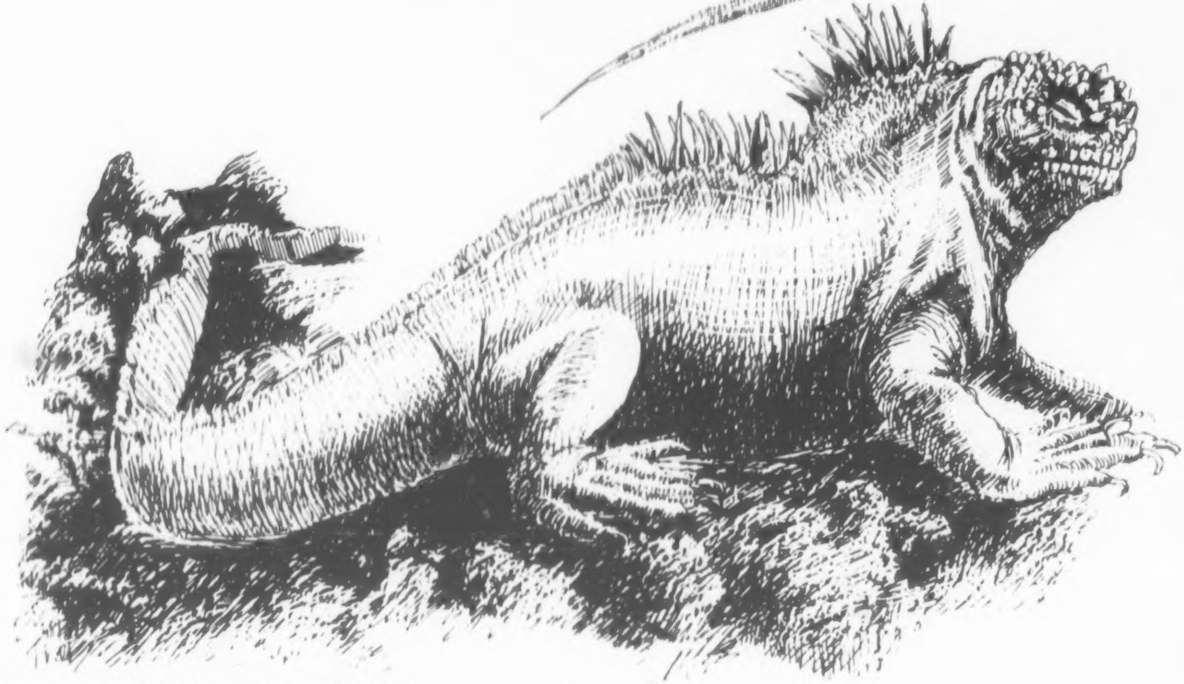
Mangrove - Several species of flowering mangrove shrubs and trees grow at the water's edge. Their branches may reach as high as 25 m (82 ft). Mangroves are able to resist salt, conserve water, and absorb oxygen from the air. Their roots are shallow but spread out over a wide distance. Mangroves send out prop roots from their branches to help anchor the plant. The tangle of their roots gives shelter to many small fish and marine animals.

Land and Marine Iguanas



Land Iguana, *Conolophus subcristatus*

These iguanas are typically about one meter in length and weigh about 6 kg (over 13 pounds). They may live for 60 years or longer. Their bodies are yellow with patches of brown. They choose dry areas where they feed on cactus and most other land plants. Each animal digs a separate burrow with a nest at one end, then guards its nest. Females lay five to fifteen eggs in a clutch and leave them unprotected. Young land iguanas are vulnerable to a wide range of predators, but no native species preys on the adults.



Marine Iguana, *Amblyrhynchus cristatus*

These iguanas are black with red, orange, and green spots, and grow up to one meter in length. They are frequently found in large groups, sunning or sleeping along the rocky shorelines. They feed underwater on seaweed and algae, swimming by sideways motions of their long tails and diving as deep as 12 meters. A large male can stay underwater for up to an hour. The marine iguana has webbed feet with claws. It drinks sea water. Salt glands in the head allow it to get rid of the excess salt by periodically spraying it from its nostrils.

Iguana Worksheet

MASTER 3.5d

Directions: *List all the differences you read about and observed between land and marine iguanas.*

Iguana Observations

Land Iguanas	Marine Iguanas

On the lines below, explain how each adaptation helps the marine iguana.

Back of Master 3.5d
Teacher Key

Iguana Observations

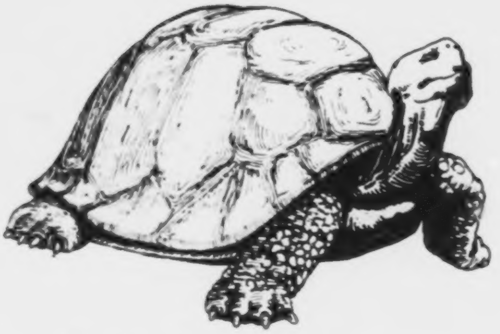
Land Iguanas	Marine Iguanas
1. Tail flattened from side to side	Tail rounded
2. Long claws	Short claws
3. Short snout	Long snout
4. Darker color	Lighter color
5. Large bumps on head	Small bumps on head

On the lines below, explain how each adaptation helps the marine iguana.

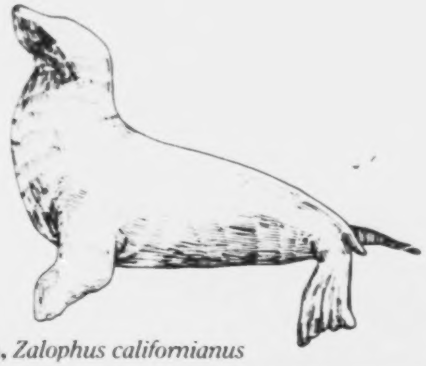
1. The marine iguana uses its flattened tail to swim. 2. Long claws allow marine iguanas to hold onto rocks underwater while feeding. 3. The short snout allows marine iguanas to eat seaweed growing close to rocks. 4. The marine iguana often feeds in cold water. Since dark colors attract heat, it can warm up quickly by lying in the sun. 5. During courtship, male land iguanas butt heads with each other. Marine igunanas do not.

Some Animals of the Galápagos Islands

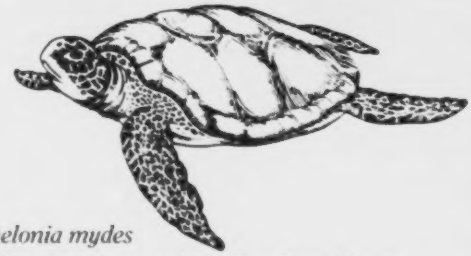
MASTER 3.5e



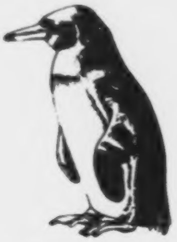
Tortoise, *Geochelone elephantopo*
This giant reptile weighs 250 kilograms (over 541 pounds) and measures 150 centimeters (almost 5 feet) across the shell. There are 11 subspecies ranging from the smallest, the saddlebacks, to the largest, the dome shaped tortoises. Tortoises eat the vegetation they find on the islands, and require large amounts of water to digest their food. Therefore, they make frequent trips to freshwater springs, always following the same well-worn trails. At dusk they push into thicker vegetation and lie down under plants and away from the paths. Tortoises lay their eggs directly on the ground. The major threats to their survival are predators who eat their eggs and competition from other species.



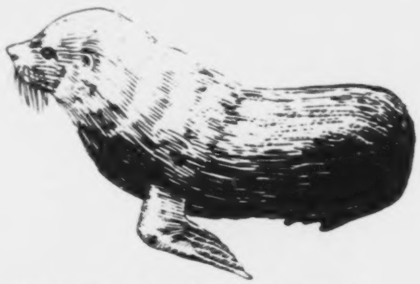
Sea Lion, *Zalophus californianus*
Like the trained sea lions in circuses and aquariums, these animals are playful and inquisitive. They live in large colonies on beaches around protected water, feeding on fish and squid. They tend to feed offshore in the daytime, and can dive as deep as 200 meters (656 feet). Males often fight over territory and for dominance. Pups, born singly, are cared for for up to three years. It is common to see one female supervising a group of pups in a shallow, protected pool while the other mother sea lions feed.



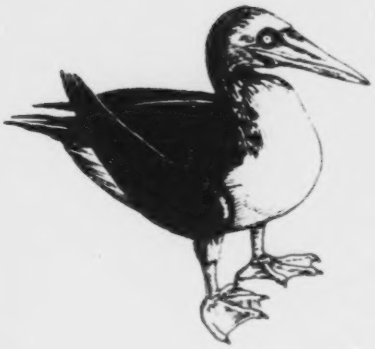
Green Sea Turtle, *Chelonia mydes*
These turtles are smaller than the tortoises. They have flippers for swimming. Mating occurs at sea, but the females come on land to lay their eggs in nests on the sand of the islands' many lagoons. Sea turtles feed on algae, fish, jellyfish, and sponges.



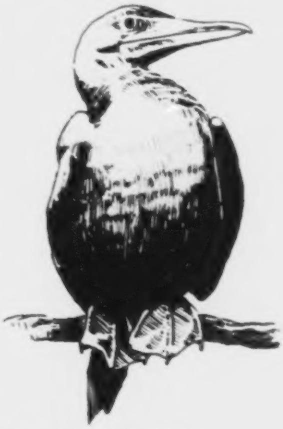
Penguin, *Spheniscus mendiculus*
Galápagos penguins, the only penguins at the equator, are smaller than penguins found elsewhere. They swim very fast under water, and live on the fish which they catch in these nutrient-rich waters. Galápagos penguins mate for life. The female lays one or two eggs in the nest. Both parents cover the nest and take turns watching the eggs.



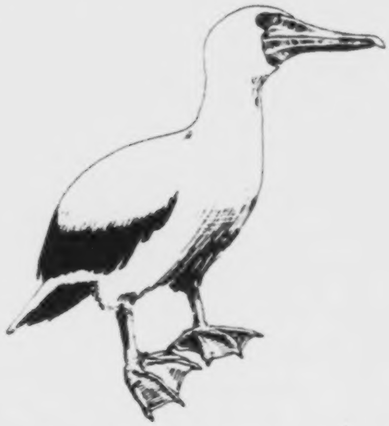
Fur Seal, *Arctocephalus galápagoensis*
The Galápagos is the only place on the equator to be inhabited by pinnipeds. The upwelling of cool, nutrient-rich waters provides fish for the fur seals. Galápagos fur seals are smaller than sea lions. Their faces are also broader and more pointed, and their front flippers are larger. They tend to live in small, scattered groups on steep, rocky slopes and feed by night in the shallow offshore waters. They can dive to depths of about 90 meters (almost 300 feet). Females give birth to one pup every two years and care for it until it is a year old.



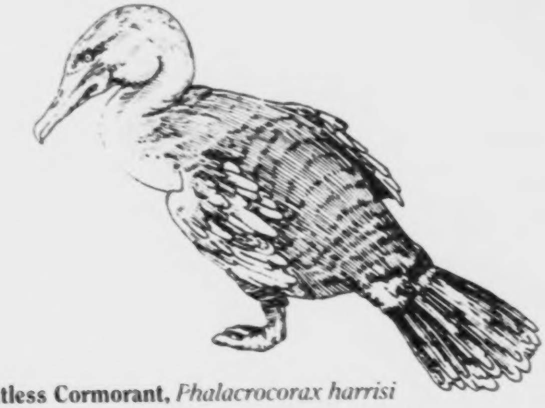
Blue Footed Booby, *Sula nebouxii*
The Galápagos blue footed booby is a very tame bird, easily spotted by tourists because of its outgoing nature and its extraordinary blue feet. This booby lives on fish it catches by diving from high cliffs into shallow coastal waters. Blue footed boobies often fish in groups; groups will also follow tour boats. The female lays two or three eggs several times a year in a shallow depression on the bare ground. Each such nest is ringed with pebbles the female has collected.



Red Footed Booby, *Sula sula*
Like all of the boobies, this is a large bird, 70-90 centimeters tall (between 2 and 3 feet) with a wingspan of 1.5 meters (almost 5 feet) and a long, pointed beak. The adult of the red footed booby, smallest of the three types, is brown with red feet and a blue bill. It can be found on tropical islands all over the Pacific. It feeds far out at sea, catching flying fish and squid. The female builds a flimsy nest of twigs in a tree or shrub, mates once a year, and lays a single egg.



Masked Booby, *Sula dactylatra*
The masked booby is the largest of the three. The adult has bright white plumage, black wings, an orange bill, and a black mask. It will fish in deep areas, but not as deep as those favored by the red footed booby. After mating the female will lay two eggs, about five days apart, in a nest similar to that of the red footed booby, but built on a cliff or a steep slope. It is common for the first hatchling to kill its younger and weaker sibling.



Flightless Cormorant, *Phalacrocorax harrisi*
Since these birds cannot swim they are limited to life close to shore. They waddle only a few meters inland for resting or nesting. Webbed feet and short stubby wings enable them to swim in shallow waters, catching fish in beaks with small pouches similar to those of pelicans. They usually nest on open flats just behind the beach, roosting on materials they have dragged from the beach. Their courtship is a kind of aquatic dance.

Compare and Contrast Worksheet

MASTER 3.5f

Compare - find similarities
Contrast - find differences

Animals I chose: ____________________ and ____________________

	Similarities	Differences
Appearance		
Food and feeding		
Sleeping habits and places to sleep		
Mating, nesting, and care of the young		

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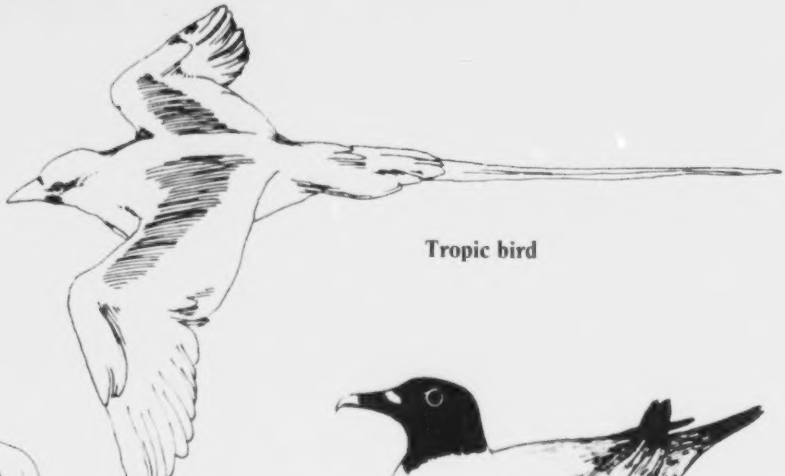
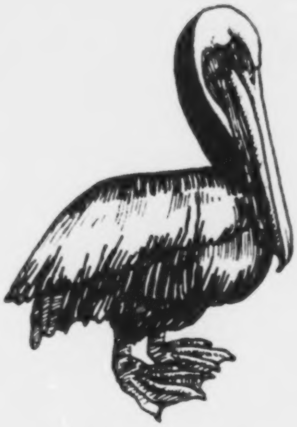
MASTER 3.5g

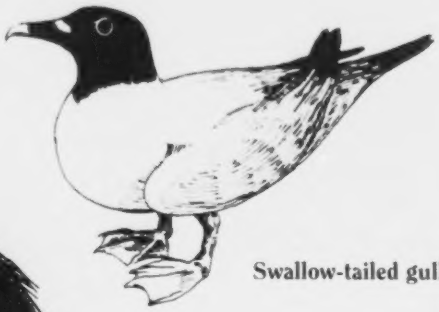
More Land Animals



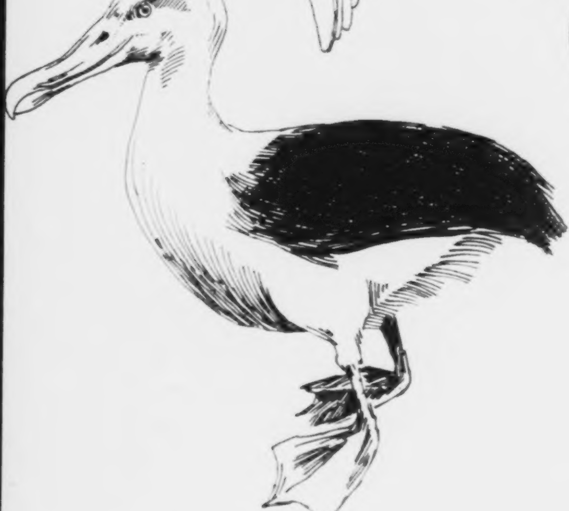
Tropic bird



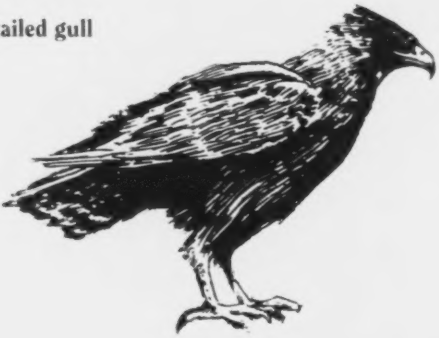
Brown pelican



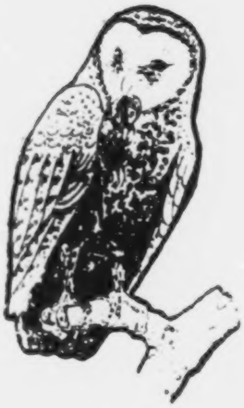
Swallow-tailed gull



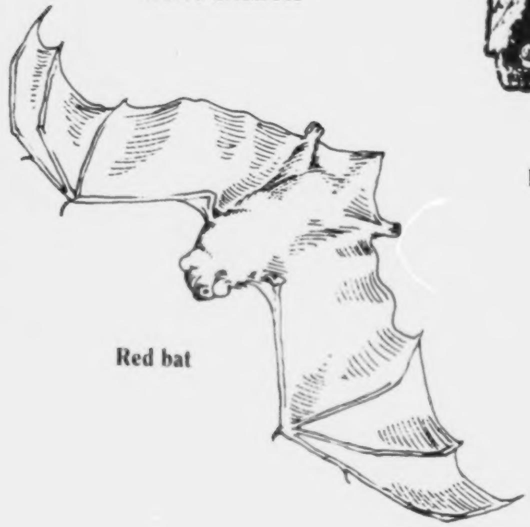
Waved albatross



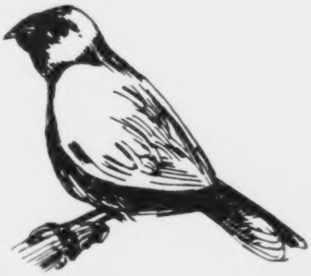
Galápagos hawk



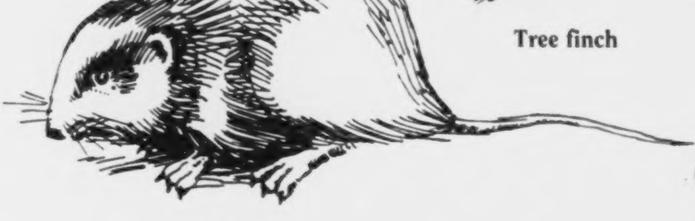
Barn owl



Red bat



Tree finch



Rice rat

ADAPTATION AND NATURAL SELECTION

3.6

ACTIVITY ONE

The Natural Selection Challenge

Rationale

This activity is a highly simplified model of the evolutionary process as it may occur in an archipelago such as the Galápagos. It illustrates how a combination of natural selection and random happenings may determine which species of a type of bird may evolve on an island.

Objectives

Students will:

Do an activity modeling the evolution of different bird species from a common ancestor.

Observe how certain variations of a species might have an increased chance of survival through natural selection.

Discuss the random nature of species evolution.

VOCABULARY

A•dapt - to gradually develop changes in response to changing circumstances.

Ar•chi•pel•a•go - a group of islands sharing common physical and locational characteristics.

Ran•dom - occurring by chance; lacking a definite plan, purpose, or pattern.

Spe•cies - a population of similar organisms that are capable of interbreeding with each other in nature and do not interbreed with any other populations.

Materials

Enough copies of the following for each student group of two or three:

- Heavy construction paper
- Master 3.6a, Playing Board and Master 3.6b, Instructions
- Master 3.6c, Event Cards and Master 3.6d, Bird Cards
- One 6-sided die for each small group
- Master 3.6e, Data Sheet
- Scissors and transparent tape

Procedure

Teacher Preparation

Before class time, make a copy of the playing board (Master 3.6a, two pages) for each small group of two or three students. Also copy the instructions, two double-sided sheets of cards, and a data sheet (Masters 3.6b through 3.6e) for each group.

TEACHER TAKE NOTE

Use the heaviest paper that your copier will accept and/or paste the board and cards on heavy paper after copying. Cut apart the game cards and assemble them in sets for student use. You may want to laminate the board and cards.

A. Introduction

Ask the class: Do any of you look *exactly* like either of your parents? Explain that no one does, because all the characteristics that make up an organism are subject to change from one generation to the next. This game demonstrates how, through natural selection and random events, different bird species might evolve in an island archipelago such as the Galápagos.

TEACHER TAKE NOTE

If time allows, increase student involvement and cut your own preparation time by recruiting students to prepare the board and cards.

B. Lesson Development

1. Direct students to gather in groups of two or three. Supply each group with tape and copies of Master 3.6a, Playing Board; Master 3.6b, Instructions; Master 3.6c, Event Cards; Master 3.6d, Bird Cards; and Master 3.6e, Data Sheet.

2. Explain to the students that each event in this activity is to be understood as happening over a period of approximately 10,000 years. Events are of two kinds:

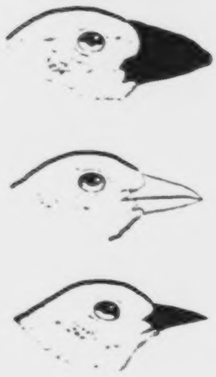
a. Adaptation: If an adaptation card is drawn from the pile, it is assumed that over a period of time, enough changes have occurred in a population of birds within a species—including changes in beak structure that allow it to take advantage of a different food supply—that it has become a different species. These changes can only happen if food the bird can eat is available on the island. If that food is not available, assume that the birds with the new beak structure could not compete successfully for food and did not survive to form a new species.

b. Migration: The islands in the Galápagos archipelago are so far apart that birds don't normally migrate between them. However, if a migration card is drawn from the pile, assume that several birds of one particular species were blown out to sea in a storm and landed on a different island. In order for this population of birds to become established on this island, its food source must be available. If the food is not available, the birds will be unable to colonize the new island.

TEACHER TAKE NOTE

The Ancestral Bird card is not with the other bird cards, but on the event card sheet. When you cut out and assemble the cards, place it on top of the bird card pile.

3. Set the scene by explaining that there must be a bird from which the other birds can evolve—an ancestral bird. Therefore, the first event of this game occurs before play begins: A group of hard-seed eating birds, the ancestral species, migrates from the mainland to Island One of the archipelago.



4. Give these instructions for preparing to play the game:

- Place the two-page playing board on the table and tape the two halves together.

- Shuffle the event cards and place them face down in the space on the board labeled Event Cards.

- Place the bird card that says Ancestral Bird on Island One. Note that the food for this bird is available on Island One.

- Separate the remaining bird cards into six piles by number and place them face up in the labeled spaces on the board.

- Place the instructions in a convenient place for reference.

5. Allow the small groups to play for ten minutes before they tally their results.

C. Conclusion

After groups tally their results and record them on the data sheet, invite one student from each group to present the group's results to the class. Compare the results and discuss why each group came up with different results. Emphasize the random nature of events, and remind students of the long span of time in which evolutionary events actually occur.

Review the basics of natural selection, using another example. Stress that most evolutionary changes neither harm nor help the organism's chance of survival. One example of this neutral type of adaptation in animals is the number of spots on a frog's side. Having three spots is neither more nor less beneficial to a frog's survival than having six spots.

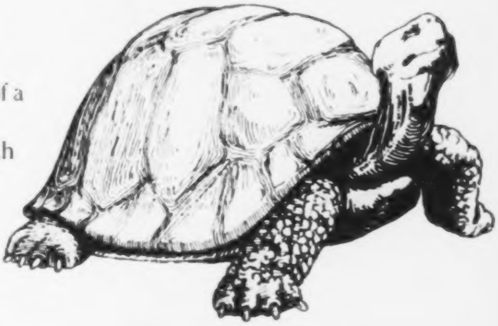
Occasionally, though, changes occur that will harm an organism's chance of survival; a frog, for example, may be born without webbing between its toes. Frogs without webbed feet would not be able to swim as well as other frogs, so they would be less likely to survive and pass this trait on to their offspring.

Occasionally, changes occur that enhance an organism's chance of survival, such as the ability to use a food source that others of its kind cannot use. One example of this kind of change is the hatching of a frog whose tongue is longer than the tongues of other frogs. This frog would be able to catch flies other frogs couldn't reach. Its chance of surviving and passing on this beneficial trait to its offspring would be enhanced. If this group of frogs should become isolated from other frogs—perhaps on an island—over a period of 10,000 years or so, changes might occur to make these frogs so different from other groups that they would form a separate species.

Random events might enhance or diminish the survival chances of these new, longer-tongued frogs. If a long-tongued frog should find itself on an island in the middle of a lake with plenty of high-flying flies, future generations of this frog will flourish. If, however, it swims to an island with no flies, and it has no ability to use other food sources, the frog and its descendents will not survive.

TEACHER TAKE NOTE

Emphasize that although certain changes may favor the survival of a species and others may hinder it, the process of adaptation is essentially random. It would be a mistake to call some changes "good" and others "bad," as if any kind of conscious choice were operating.



ACTIVITY TWO
The Tomato and the Tortoise

Rationale

Many different kinds of relationships may be observed within the Galápagos ecosystem. Students are probably more familiar with predator/prey relationships than with mutualistic relationships such as that between the tomato and the tortoise.

Objectives

Students will:

Observe the effect of acid (HCl) on tomato seeds.

Relate their observations to interspecific relationships in the Galápagos.

Materials

For each small group:

- Three small jars (baby food size) or waxed paper cups
- Marking pens
- Three tomatoes

VOCABULARY

Ger•min•a•tion - the development of a sprout or young plant from a seed that has been moistened.

Mu•tu•al•ism - a relationship between two creatures in which both receive some benefit. (*Mutualistic* is the adjective form.)

Pre•da•tion - a relationship in which one creature lives by killing and eating another. (One party in this relationship is called the predator and the other is its prey.)

Materials

- Serrated knife
- Tablespoon
- Tap water
- Dilute hydrochloric acid (0.1 mol. HCl) to simulate stomach acid
- Paper towels
- Strainer
- Three plastic zipper bags
- One copy of Master 3.6f, Class Data Table

TEACHER TAKE NOTE

HCl is sold in hardware stores in a solution called muriatic acid. Dilute 1 mL of acid with 99 mLs of water for proper strength.

Procedure

A. Introduction

Explain to the class that plants in dry areas develop thick gelatinous seed coats to conserve the moisture inside the seed. Before such seeds can germinate, the seed coat must be cut, scratched, or softened in some way to allow water to enter. Only about one percent of the seeds of the Galápagos tomato (*Lycopersecon esculentum*) will germinate under normal weather conditions. If a tortoise eats a tomato, however, the seeds will remain in the tortoise's stomach for up to three weeks while digestive acid (HCl) dissolves the gelatinous coating. When the seeds are passed from the tortoise's intestines they germinate readily. Thus, what appears to be only a herbivore eating a plant is actually a mutualistic relationship that benefits both organisms.

TEACHER TAKE NOTE

CAUTION: Students should wear protective clothing while working with acid in the first part of this activity.

B. Lesson Development

1. Divide the class into groups of three or four students each. Assign each group a letter, A through G. Distribute the tomatoes, jars or cups, knives, spoons, and marking pens. Place containers of water and diluted acid in a central location. Give these directions:

- Label the first container *Water*, the second *Acid*, and the third *Air*.

- Cut the first tomato in half. Use a spoon to scoop out the pulp with the seeds and place it in one of the cups or jars. Repeat with the other tomatoes.

- Cover the seeds and pulp in the first container with tap water. Cover the seeds and pulp in the second with diluted acid. Leave the seeds and pulp in the third exposed to the air.

2. At the beginning of class the next day, supply each group with a strainer and several paper towels. Instruct students to drain, rinse, and dry the seeds and return them to the labeled containers.

TEACHER TAKE NOTE

This activity will take brief periods of time on several days over a span of about two weeks.

3. Provide each group with a copy of Master 3.6f, Class Data Table, three paper towels, and three zipper bags. Give these directions:

- Record your data in the row that corresponds to your group's letter, A through G.

- Count the number of seeds in each container and record it in the start box on your data table.

- Dampen one of the paper towels, spread the seeds from the first container on one side of it, and fold the towel over to cover the seeds.

- Place the folded towel with the seeds in a zipper bag and label the outside of the bag to match the appropriate container—Water, Acid, or Air.

- Repeat with the rest of the seeds.

4. Every day for ten days, remind students to check their bags to be certain the towel is still damp. Students in each group can take turns checking and adding water as necessary.

5. After ten days, have students open the towels and count the seeds that have germinated, then record their data on the table.

6. Ask students to calculate the percentage of seeds from each container that germinated. Write this formula on the board for them to use:

$$\frac{\text{Number of seeds germinating}}{\text{Number of seeds planted}} \times 100 = \_\_\_\% \text{ Germination}$$

7. After each group has reported its results, ask students to total the data and calculate the percentages for the class. Construct a bar graph of the class results on the board.

TEACHER TAKE NOTE

If a three-day weekend or other school holiday occurs during this time, you may want to take the packets home and add water at least once.

C. Conclusion

Challenge students to explain the relationship between the activity they have completed and the germination of tomato plants in the Galápagos. Ask:

- Which of the three samples of seeds was most like the environment in a tortoise's digestive system? (the acid-soaked seeds)

- What role does acid play in helping seeds to germinate? (Stomach acid dissolves the seeds' coating.)

- Does soaking seeds in acid produce a higher rate of germination than starting dry seed? (Yes.)

- Does soaking in water have the same effect? (It has some effect, but germination is slower than in acid.)

- Do you think that animals help the seeds of other plants to sprout in a similar way? (Yes.)

Adaptations

For younger students

Try repeating these steps with other plant seeds to find out if they are affected in the same way.

For older students

1. Experiment with the length of time allowed for soaking and sprouting. Record data and compare results.

2. Experiment with different varieties of tomato seeds. Record data and compare results.

This activity is based on Contributions to Science from the Galápagos *by Robert L. Bowman, in Perry, Roger, ed.,* Key Environments: Galápagos, *page 297.*

ACTIVITY THREE

Owl Pellets: Time Capsules from Lava Tubes

VOCABULARY

La•va tube - a cave formed when molten rock flows downhill beneath the surface of hardened lava.

Stra•ta (s. **stratum**) - layers of rock or other material formed at different periods in geologic time.

Rationale

Galápagos barn owl pellets are found in lava tubes and other sheltered places in the islands—caves, overhangs, trees, barns, and steeples. Analysis of fossil Galápagos barn owl pellets enables scientists to describe past populations of rodents on the Galápagos Islands.

Objectives

Students will:

Cut out pictures of bones from a fossil giant rat, *Megaoryzomys curioi*, formerly of Santa Cruz Island.

Reconstruct the skeleton of the extinct giant rat.

Discuss reasons for the extinction of the giant rat.

Materials

- Overhead projector
- Transparency made from Master 3.6g, Lava Tube Formation
- Back of Master 3.6g, Formation of a Lava Tube, Teacher Background Reading
- Student copies of Master 3.6h, Bones of a Giant Rat
- Scissors
- Glue
- Construction paper for mounting skeleton
- Transparency made from Master 3.6i, Intact Rat Skeleton

TEACHER TAKE NOTE

If you did not teach the last part of Lesson 3.2, which contains the geology background for this unit, you may have to provide a more extensive explanation of volcanism.

Procedure

A. Introduction

Tell students that the Galápagos barn owl, *Tyto punctatissima*, roosts in lava tubes during the day and at night hunts rodents, snakes, lizards, and even, when the rodent population is low, other birds. It swallows its prey whole and digests the meat inside its first stomach. Undigested bones and fur, scales, and feathers are regurgitated as pellets about 18 hours later.

Project Master 3.6g, Lava Tube Formation. Summarize the background material for your students.

B. Lesson Development

1. Describe to students how owl pellets accumulate on the floors of lava tubes over centuries, creating strata of bones and organic debris. Within each pellet are the complete skeletons of prey the owl has eaten. Analysis of the pellets reveals information about the kind and abundance of the owl's prey. Carbon dating can identify the age of the pellets. From these pellets, scientists have discovered an extinct

rodent species (the Galápagos giant rat) and previously unknown living species. Since the giant rat died out in historic times, scientists assume that it became extinct some time after domestic cats and the black rat, *Rattus rattus*, were introduced into the Galápagos.

2. Distribute scissors, glue, construction paper, and copies of Master 3.6h, Bones of a Giant Rat.

3. Instruct students to cut out the bones and assemble them on the construction paper to make complete rodent skeletons.

4. Project Master 3.6i, Intact Rat Skeleton, and have students compare their rodent skeletons with the one pictured.

C. Conclusion

Ask students what they learned from this lesson about the history of the owls and rodents of the Galápagos Islands. Do they have any theories about why the giant rat died out? (Before the cats and other rats were introduced, the giant rat, like most animals of the Galápagos, probably had few natural enemies. We can reconstruct reasons for their extinction, as we can reconstruct their skeletons, but our findings will never be conclusive.)

TEACHER TAKE NOTE

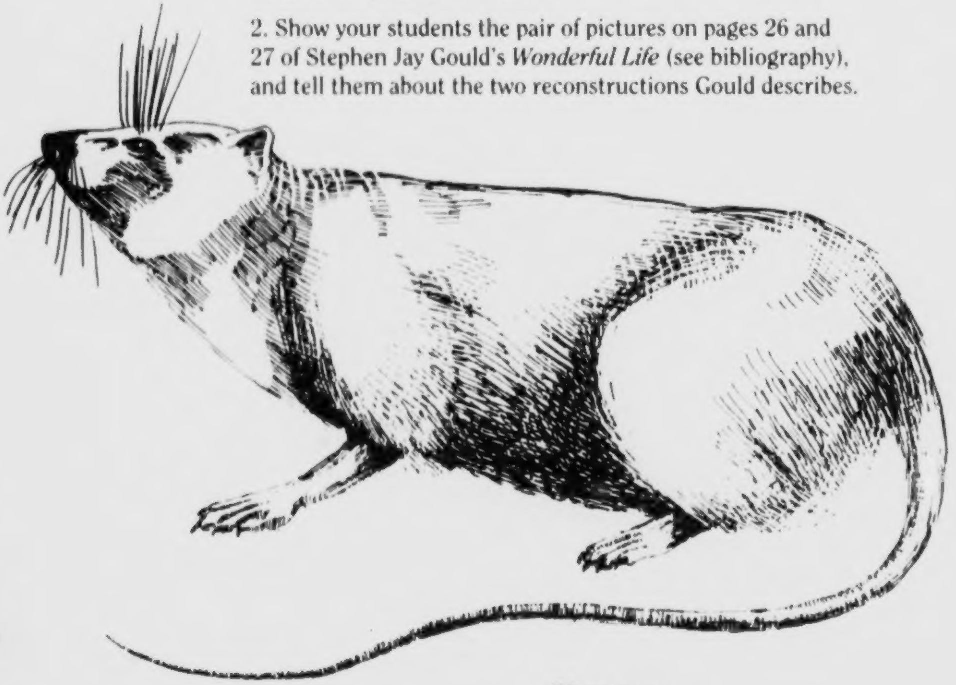
If student reconstructions vary, take this opportunity to explain that professional scientists often disagree on skeletal and fossil reconstruction. Close relatives of these species are alive today, so we know what they look like. Scientists reconstructing extinct species, however, are practicing a form of educated guesswork.

Adaptations

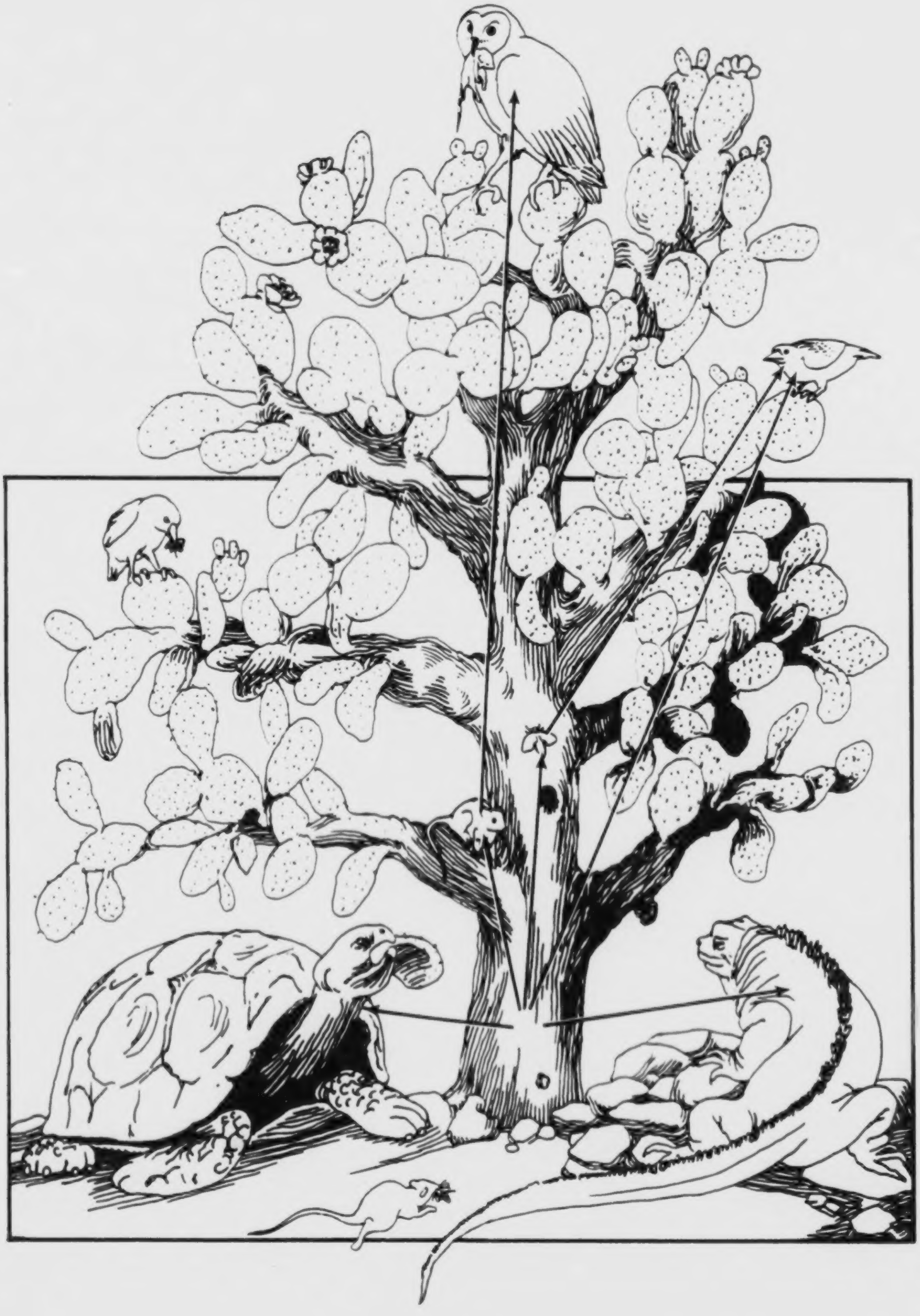
For all ages

1. You may want to order actual owl pellets from a scientific supply house for students to dissect, either before or after this activity. One source is Creative Dimensions, PO Box 1393, Bellingham, WA 98227.

2. Show your students the pair of pictures on pages 26 and 27 of Stephen Jay Gould's *Wonderful Life* (see bibliography), and tell them about the two reconstructions Gould describes.



Giant Rat



A Barn Owl Food Web

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Playing Board

THE NATURAL

Large crushing beak 1.

Small crushing beak 2.

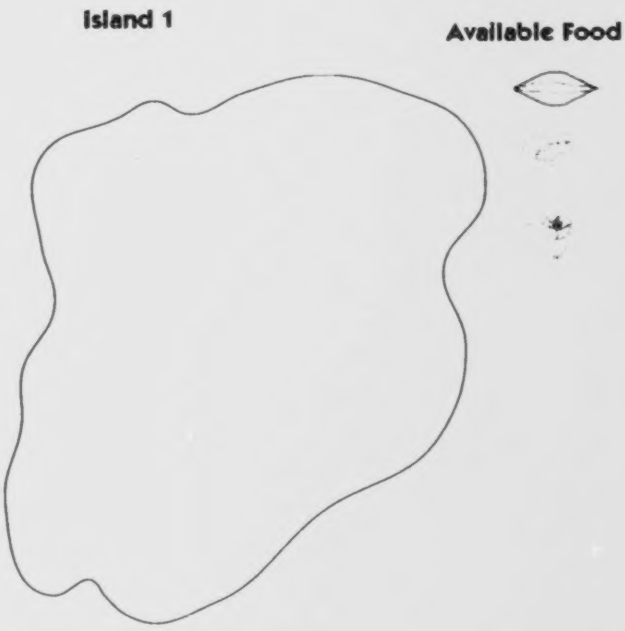
Fruit-eating beak 3.

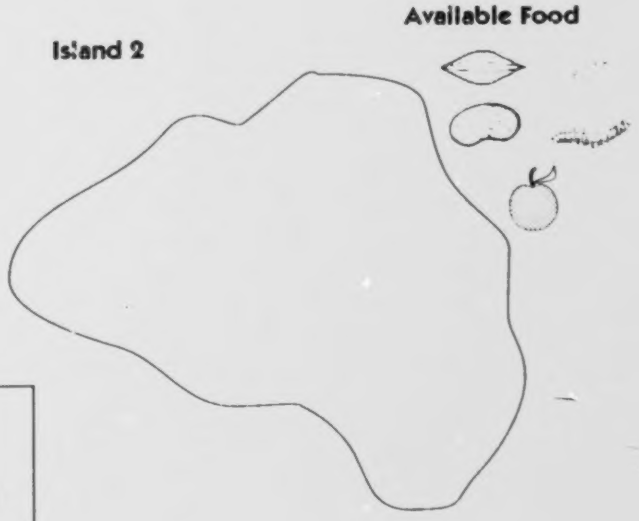
Wood-chiseling beak 4.

Tweezer-like beak 5.

Nectar-sipping beak 6.

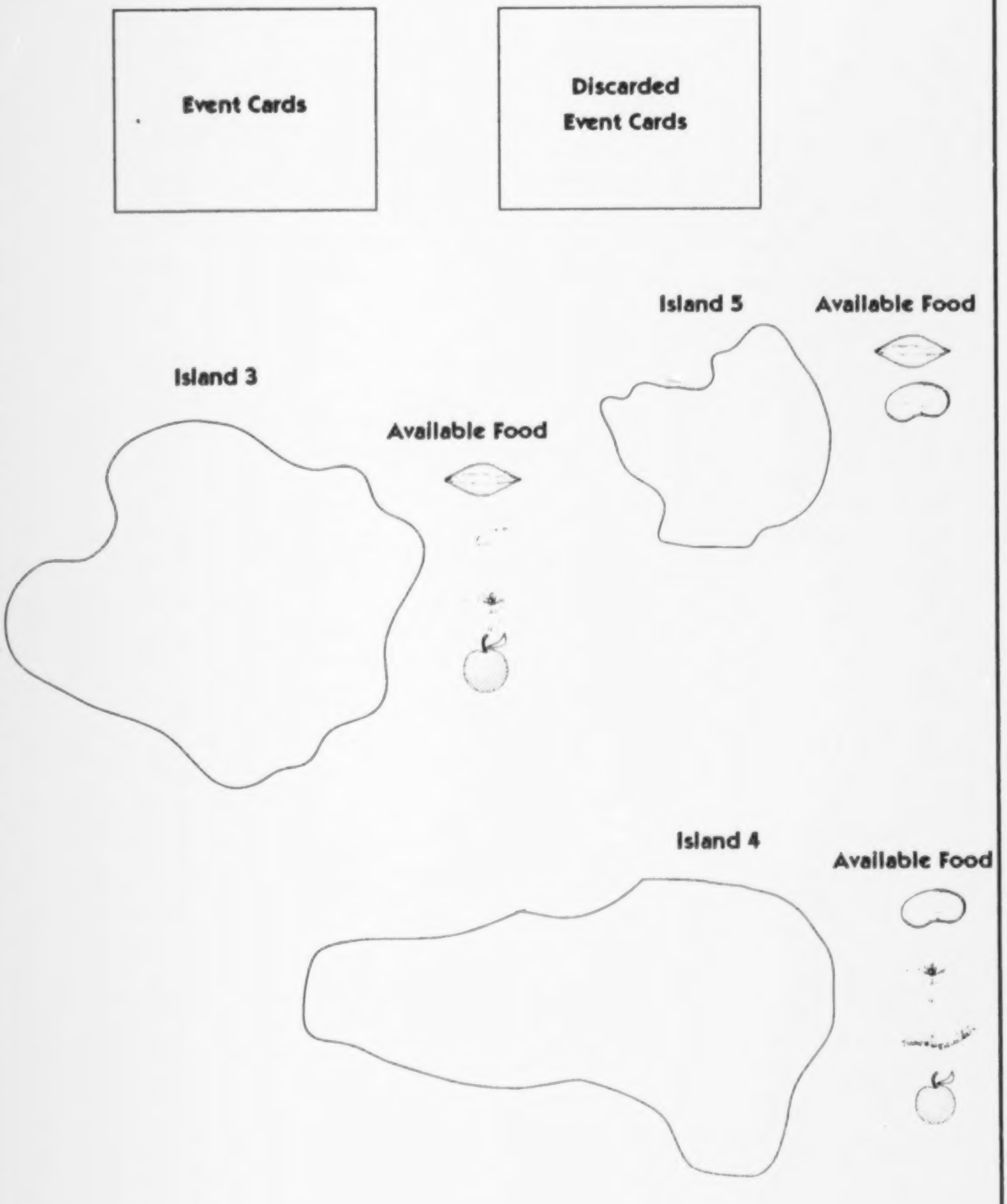
Discarded Bird Cards


Island 1
Available Food


Island 2
Available Food

(Cut along dashed line and tape to other half of game board.)

SELECTION CHALLENGE


Event Cards
Discarded Event Cards
Island 5
Available Food
Island 3
Available Food
Island 4
Available Food

(Cut along dashed line and tape to other half of game board.)

MASTER

3.6b Instructions

1. Draw an event card. (Until birds have arrived on the other islands, all instructions apply to Island One.)

   a. If the card is an adaptation card, consult the beak and seed key below to learn what type of food that bird is adapted to eat.

   - If its food is available, add the corresponding bird card to the other bird cards on the island and discard the used event card.
   - If its food is not available, leave the bird card where it is. Discard the used event card.

   b. If the card is a migration card, take a card representing the type of bird that is migrating and place it on the new island. (The entire species will move unless otherwise specified.) Discard the used event card.

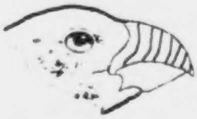
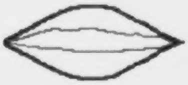
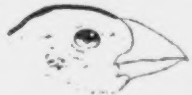
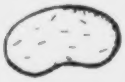
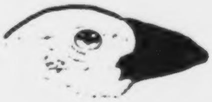
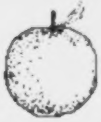
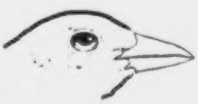
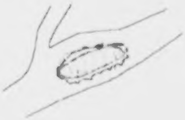
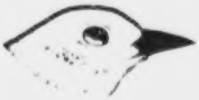
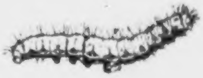
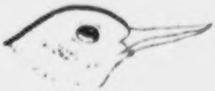
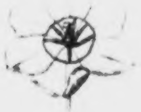
   - If its food is available, place the corresponding bird card on the island and discard the used event card.
   - If its food is not available, leave the bird card on the island where it is. Discard the used event card.

2. If birds are present on two or more islands, call out the number of an island that has birds at the beginning of each turn. Then draw an event card and proceed as above, beginning on the island you called.

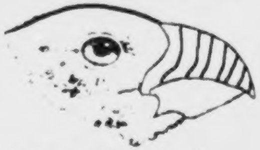
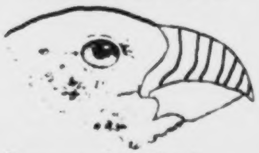
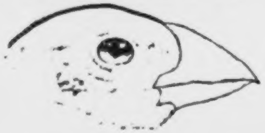
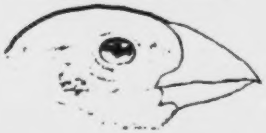
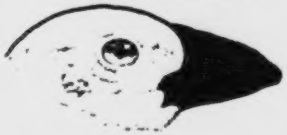
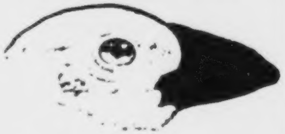
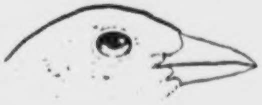
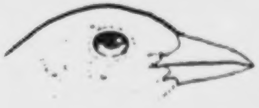
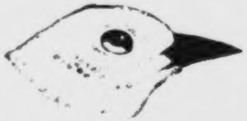
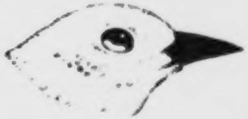
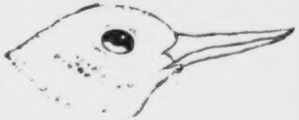
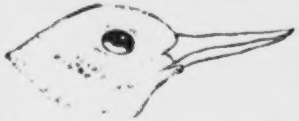
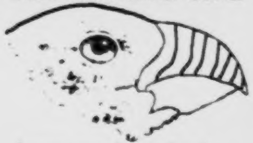
   - If the card shows a bird that already exists on that island, draw again.
   - If a migration card names the island where a bird already is, draw again.
   - If a migration card is drawn and more than one type of bird is on the starting island, roll the die and move the bird whose number comes up first.
   - If the ancestral bird dies out for lack of food, begin a new game immediately.

3. When all the event cards have been used once, shuffle the cards and begin again. The activity ends when the teacher calls time.

4. At the end of the last game, record on the data sheet which birds are living on which islands, and prepare your report to the class.

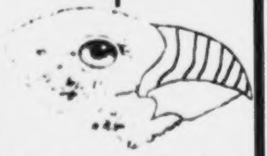
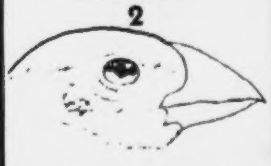
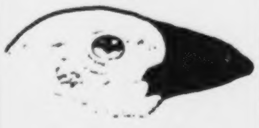
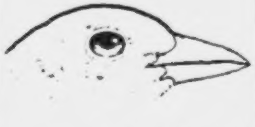
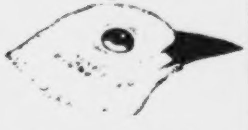
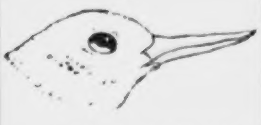
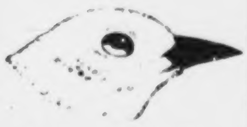
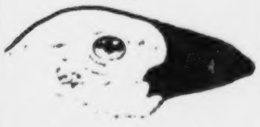
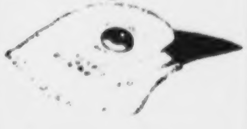
large crushing beak			hard seeds
small crushing beak			soft seeds
fruit-eating beak			fleshy fruits
wood-chiseling beak			grub inside branch
tweezer-like beak			caterpillars
nectar-sipping beak			flower nectar

Event Cards

Adaptation Card  large crushing beak 1	**Adaptation Card**  large crushing beak 1	**Adaptation Card**  small crushing beak 2	**Adaptation Card**  small crushing beak 2	**Adaptation Card**  fruit-eating beak 3
Adaptation Card  fruit-eating beak 3	**Adaptation Card**  wood-chiseling beak 4	**Adaptation Card**  wood-chiseling beak 4	**Adaptation Card**  tweezer-like beak 5	**Adaptation Card**  tweezer-like beak 5
Adaptation Card  nectar-sipping beak 6	**Adaptation Card**  nectar-sipping beak 6	**Migration Card** MIGRATE TO ISLAND 1.	**Migration Card** MIGRATE TO ISLAND 1.	**Migration Card** MIGRATE TO ISLAND 2.
Migration Card MIGRATE TO ISLAND 2.	**Migration Card** MIGRATE TO ISLAND 3.	**Migration Card** MIGRATE TO ISLAND 3.	**Migration Card** MIGRATE TO ISLAND 4.	**Migration Card** MIGRATE TO ISLAND 4.
Migration Card MIGRATE TO ISLAND 5.	**Migration Card** MIGRATE TO ISLAND 5.	**Migration Card** MOVE HALF OF SPECIES TO ISLAND 2. LEAVE BIRD CARD BEHIND AND MOVE A NEW ONE W/ THE SAME NUMBER.	**Migration Card** MOVE HALF OF SPECIES TO ISLAND 4. LEAVE BIRD CARD BEHIND AND MOVE A NEW ONE W/ THE SAME NUMBER.	**Ancestral Bird Card**  large crushing beak 1

MASTER 3.6d

Bird Cards

Bird Card 1  large crushing beak	**Bird Card** 2  small crushing beak	**Bird Card** 3  fruit-eating beak	**Bird Card** 4  wood-chiseling beak	**Bird Card** 5  tweezer-like beak	**Bird Card** 6  nectar-sipping beak
Bird Card 1 large crushing beak	**Bird Card** 2 small crushing beak	**Bird Card** 3 fruit-eating beak	**Bird Card** 4 wood-chiseling beak	**Bird Card** 5  tweezer-like beak	**Bird Card** 6 nectar-sipping beak
Bird Card 1 large crushing beak	**Bird Card** 2 small crushing beak	**Bird Card** 3  fruit-eating beak	**Bird Card** 4 wood-chiseling beak	**Bird Card** 5  tweezer-like beak	**Bird Card** 6 nectar-sipping beak
Bird Card 1 large crushing beak	**Bird Card** 2 small crushing beak	**Bird Card** 3 fruit-eating beak	**Bird Card** 4 wood-chiseling beak	**Bird Card** 5 tweezer-like beak	**Bird Card** 6 nectar-sipping beak
Bird Card 1 large crushing beak	**Bird Card** 2 small crushing beak	**Bird Card** 3 fruit-eating beak	**Bird Card** 4 wood-chiseling beak	**Bird Card** 5 tweezer-like beak	**Bird Card** 6 nectar-sipping beak

Data Sheet

MASTER
3.6e

List which birds migrated to or evolved on each island:

Island 1 ______________________________

____

____

____

Species surviving at the end of game: ______________________________

Island 2 ______________________________

____

____

____

Species surviving at the end of game: ______________________________

Island 3 ______________________________

____

____

____

Species surviving at the end of game: ______________________________

Island 4 ______________________________

____

____

____

Species surviving at the end of game: ______________________________

Island 5 ______________________________

____

____

____

Species surviving at the end of game: ______________________________

MASTER 3.6f

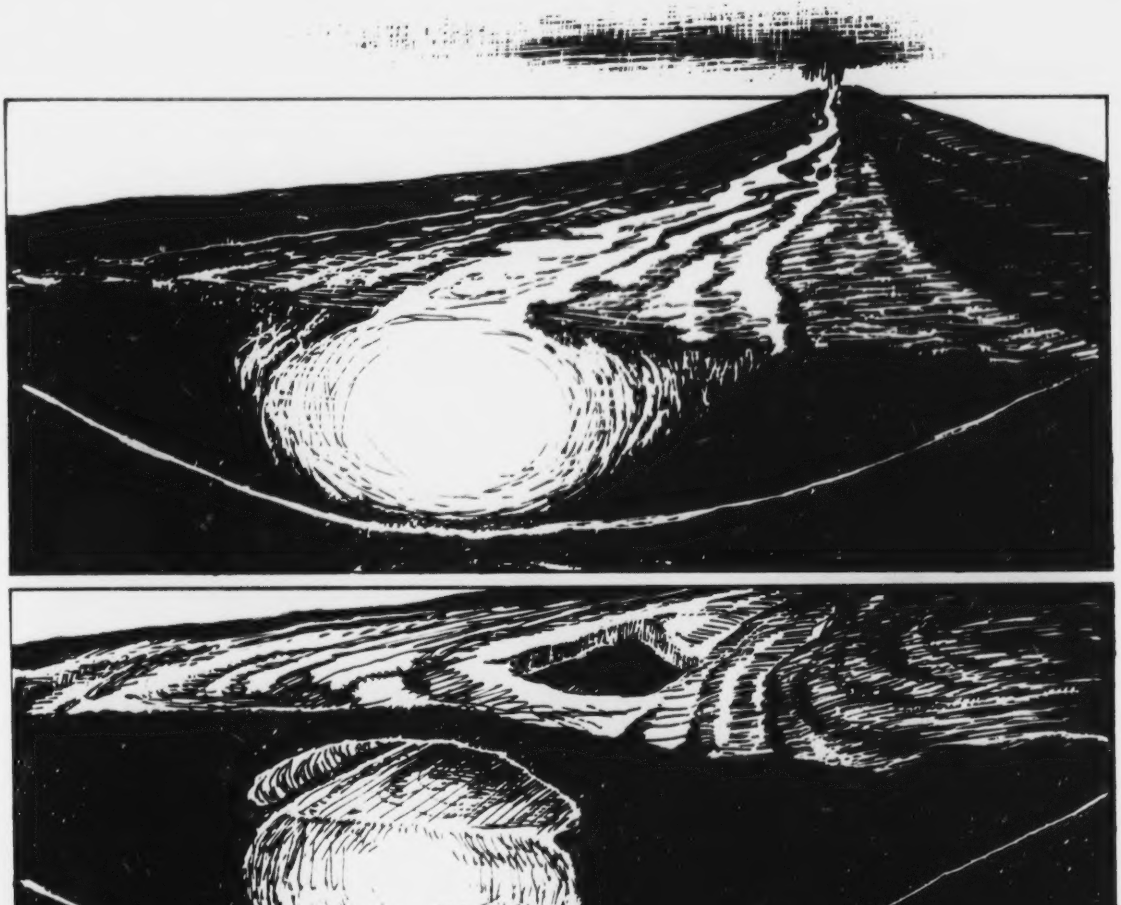
Class Data Table

Team	Air		Water		Acid		Percent Germinated	
A	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
B	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
C	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
D	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
E	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
F	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
G	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
Class Total	Start	Number Germinated	Start	Number Germinated	Start	Number Germinated	Number Germinated	**Percent**
							Start	
Total % Germ-inated	Number Germinated	**Percent**	Number Germinated	**Percent**	Number Germinated	**Percent**	**Number Germinated**	**Percent**
	Start		Start		Start		**Start**	

$$\frac{\textbf{Number of seeds germinated}}{\textbf{Number of seeds planted}} \times 100 = \%\ \textbf{Germination}$$

Lava Tube Formation

MASTER
3.6g



Back of Master 3.6g

Teacher Background Reading

Lava Tube Formation

During the land exploration phase of the JASON Galápagos expedition, the team members may encounter lava tube caves. These caves and tunnels form during lava flows and serve as conduits for lava during the eruption. After the eruption, openings into lava tubes serve as nesting sites for birds and often become traps for predators and other animals that fall into the entrances.

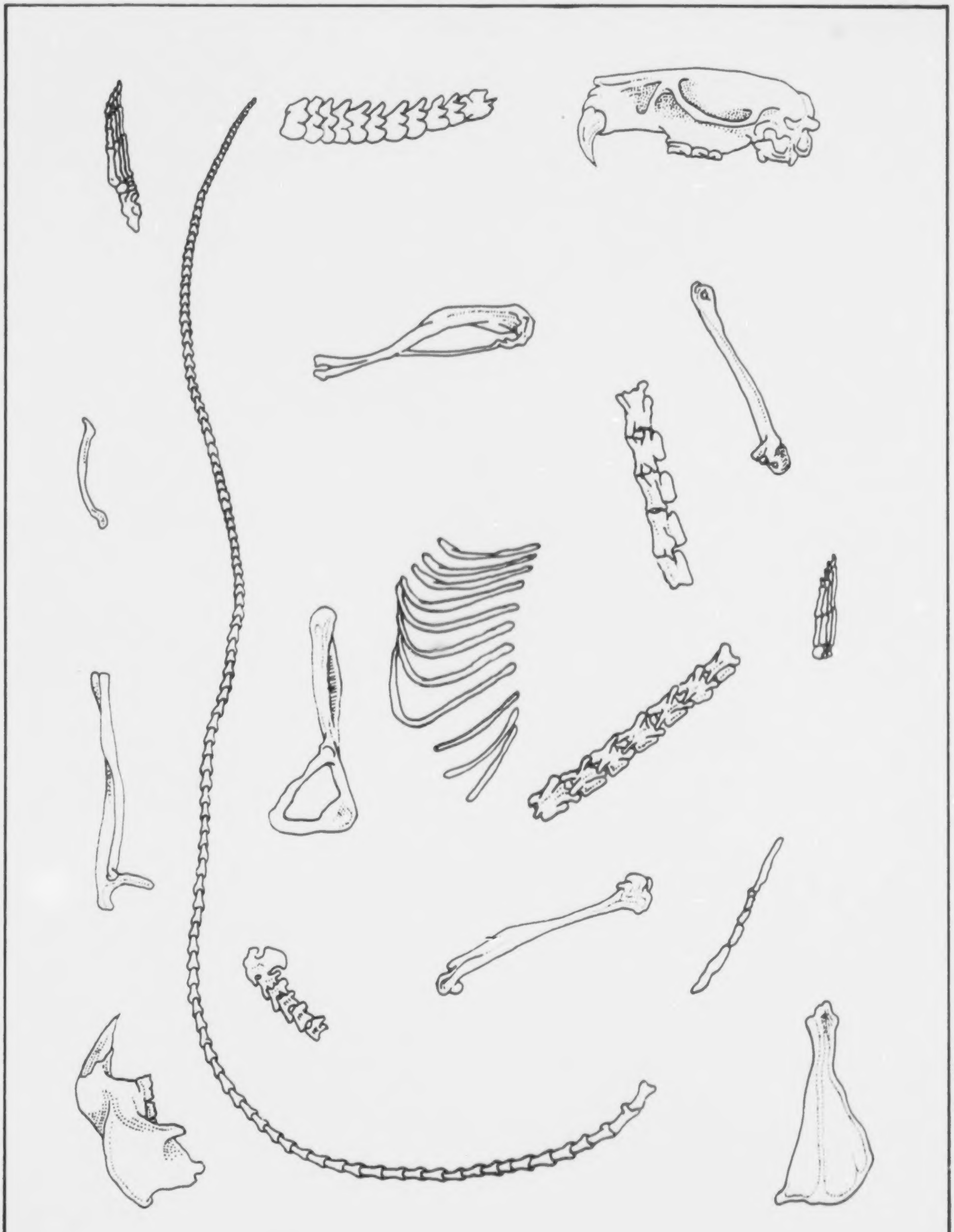
In the initial phase of a lava flow (top panel), molten material from the volcano erupts and flows across the surface of the land, following the low places in the same manner as a stream of water. Often these low places are between other flows that have erupted and have cooled to form ridges. As the flow progresses, the lava begins to cool around the margins and in contact with the ground surface, while the center of the flow remains liquid and continues to flow downslope, forming a meandering stream. The liquid material in the center overflows the edges, building up the sides to form a natural levee, and continues to cool from the outside edges toward the center. Eventually the flow will cool enough to form a surface crust over the top of the center, enclosing the molten lava.

In the next phase (middle panel) of lava tube formation, lava material continues to flow through the tube which has now roofed over. As the flow front advances, lava drains out of the tube and is replaced by more lava from the volcano. A lava tube therefore serves as a conduit for lava from the volcano to the flow front, which can be located some distance from the vent area. Under normal circumstances, the lava would cool before it could travel a great distance, but because of the insulating qualities of the solidified basalt, heat remains in the flow to keep it molten. As long as the lava drains out the bottom of the tube and is replaced by fresh lava from the vent it will serve as a conduit. But if the flow should slow down or the lower end should become plugged, the lava flow in the tube would start to cool and form a surface on top of the flow inside the tube. Lava flows will sometimes subside in stages, leaving several of these flow surfaces plastered to the walls as *tide marks*. When the flow stops completely the tube will drain, the flow will cool, and ceiling blocks will fall out, forming natural openings to the surface called *sinks*.

A lava tube explorer (final panel) finds several tide marks inside this cave indicating the eruptive history of the flow. Predators will chase prey into the caves and become trapped along with the prey. Their remains will serve as fossil evidence for later explorers. Birds of prey and other birds, as well as some mammals, will take advantage of the natural openings and the spaces between the broken blocks at the entrance to build nests. Birds of prey will eat their prey and then regurgitate the undigested materials as pellets. These pellets found at nest sites are valuable indicators of the other types of life found in the area and of the interdependence of animals in the food chain.

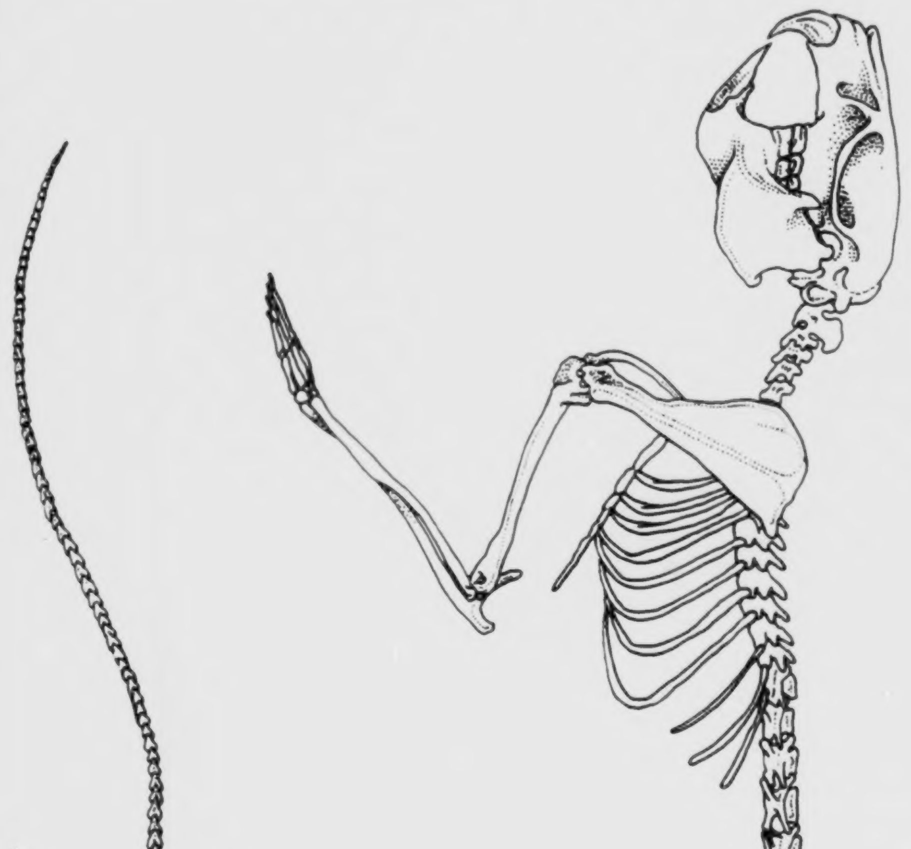
Bones of a Giant Rat

MASTER 3.6h



MASTER 3.6i

Intact Rat Skeleton



GALÁPAGOS ISLANDS MARINE FOOD WEB

3.7

ACTIVITY ONE

Build a Food Web

Rationale

A food web shows how organisms depend on each other for energy and nutrients. In this activity students will build food webs for organisms that may be encountered by the JASON scuba diver and the robot JJ while they explore Galápagos coastal waters.

Objectives

Students will:

Make food webs showing the feeding relationships among organisms.

Predict which organisms the diver might encounter in the nearshore waters.

Predict which organisms JJ might encounter in the deeper, colder waters.

Materials

- Transparency made from Master 3.7a, Location of Galápagos Marine Organisms
- Overhead projector
- Back of Master 3.7a, Teacher Background Information
- Student copies of Master 3.7b, Galápagos Marine Organisms
- Student copies of Master 3.7c, Trophic Levels of Galápagos Organisms
- Butcher paper for posters of the Galápagos Food Web
- Colored pencils, pens, or crayons
- Transparent tape

Procedure

A. Introduction

1. Project Master 3.7a and discuss the organisms found at various depths.

2. Explain the difference between a food chain and a food web, using the organisms of the Galápagos as examples.

Two examples of simple food chains are given on the next page. Write these on the chalkboard. Explain to students that the arrows point in the direction of food (energy) flow. Point out also that in the first example, the turtle obtains its food from seaweeds that grow attached to rocks in shallow coastal

VOCABULARY

Al•gae - marine plants, including seaweeds and tiny floating plants called phytoplankton. (**Algae** is plural; **alga** is singular.)

Al•gal bloom (also called **plankton bloom**) - an unusually high concentration of tiny floating algae, or phytoplankton. In the Galápagos, a plankton bloom occurs within a few days of an upwelling that brings cold, nutrient-rich waters to the surface.

Ben•thic or•gan•isms - plants and animals that live permanently in or on the ocean bottom.

Car•ni•vores - animals that eat other animals.

Coast•al o•cean - shallow ocean water less than 200 meters deep.

Com•men•sal•ism - A relationship in which two or more organisms live in close association, and one may derive some benefit, but neither one harms nor is parasitic on the other.

Com•pe•ti•tion - rivalry between organisms for food, shelter, or control of a territory.

Con•sum•ers - organisms that cannot produce their own food but must feed on producers or animal matter.

Fil•ter feed•ers - organisms that obtain their food by straining small organisms or bits of food from the water.

Hab•i•tat - the environmental conditions in which an organism lives.

Her•bi•vores (also called **grazers**) - animals that eat producers; these animals are in the second trophic level.

areas. In the second example, small fish obtain their food from plankton, the floating algae and tiny animals that drift in the water.

Seaweed——>Turtle——>Shark

Phytoplankton—>Zooplankton—>Plankton-eating fish—> Squid—>Penguin—>Shark

3. Compare these examples of simple food chains with a more complex food web. Be sure students understand that a food *chain* shows relationships between specific organisms, while a food *web* shows interconnections among all the organisms in the same ecosystem.

B. Lesson Development

1. Distribute student copies of Master 3.7b, Galápagos Marine Organisms and Master 3.7c, Trophic Levels of Galápagos Marine Organisms. Have students use the drawings on Master 3.7b, Galápagos Marine Organisms, to create a poster or bulletin board mural of a Galápagos food web, working either individually or in groups. Students can color the pictures on the master, then cut them out and glue them onto their poster or mural to produce an accurate representation of a Galápagos food web.

(To enlarge drawings to scale or to full size, use an overhead projector. Start by transferring the outline of the organism onto a transparent overhead sheet. Project the image onto butcher paper, moving the projector away from the paper until the image reaches the desired size. Trace the image onto the paper.)

2. Build a class discussion around the completed poster of the Galápagos food web. Introduce the word pairs *producer* and *consumer* and *herbivore* and *carnivore*, then ask:

- Where on your poster do you find producers? consumers? herbivores ? carnivores?

- Find examples of the following relationships among organisms:

a. *symbiosis* (Example: stony reef-building corals and zooxanthellae, the green, photosynthetic algae that live in the tissues of the coral polyps. Another example is the barber butterflyfish that sets up a cleaner station to remove parasites from the bodies of other fish.)

b. *commensalism* (Cleaner wrasses picking parasites off other fish; barnacles on whales)

c. *parasitism* (Frigate bird robbing other sea birds of their catch)

d. *predation* (Sharks preying on turtles, larger fish on smaller fish, cormorants on fishes, penguins on fishes, whales on small invertebrates and plankton)

e. *competition* (Damselfish, turtles, marine iguanas, sea urchins, and grazing fishes, including parrotfish and surgeonfish, all feed on the seaweed *Ulva*, so each competes with the others for food.)

- Why are killer whales described as top carnivores? (They are the largest carnivore; no other carnivore preys upon them.)

VOCABULARY

Mu•tu•al•ism - a relationship between two creatures in which both receive some benefit.

Nu•tri•ents - substances necessary for growth and life. In the ocean, the most important nutrients are dissolved substances necessary for plant growth.

Om•ni•vores - animals that eat both plants and animals.

Par•a•site - an organism that derives nutrients or shelter from another species, negatively affecting its host. The host loses sustenance, while the parasite loses independence. (Such a creature's mode of existence is called **parasitism**.)

Pho•tic zone - the part of the ocean where sunlight can reach and photosynthesis is possible.

Pop•u•la•tion - a group of individuals of the same species that occupy the same geographic region and interbreed from generation to generation.

Pro•duc•ers - green plants and specialized bacteria capable of making food from simple dissolved matter. Most producers are green plants that, in the presence of sunlight, combine water and carbon dioxide to make sugar and oxygen, a process called **photosynthesis.**

Scav•en•ger - an animal that feeds on dead or decaying matter.

Ses•sile - permanently attached, not free-moving.

Sym•bi•o•sis - a close interrelationship between two different organisms that may be, but is not necessarily, of benefit to each. (*Parasitism* [harmful to host], *commensalism* [neutral], and *mutualism* [beneficial] are different types of symbiotic relationships.)

3. Ask the class: At which levels of the Galápagos food web would you expect to find:

- the largest population?
- the smallest population? (Populations are largest in trophic level 1, at the bottom of the food web, and grow smaller with each successive level. Thus, the algae comprise the largest population, and the top carnivores [trophic level 6] are the smallest population.)

- the largest adult organism?
- the smallest adult organism? (Both questions refer to body size and weight. The smallest creatures are in the lowest level. The killer whale in trophic level 6 and the humpback whale in level 3 are the largest organisms listed on Master 3.7c.)

4. Discuss how changes in the environment could affect populations of organisms, asking students what they think would happen to the marine iguanas if:

- the ocean temperature increased and the ulva (green algae) disappeared? (*Ulva*, a green alga that grows attached to rocks in shallow water, is the primary food source for the marine iguana. Other algae provide much less nutrition for this iguana. Without ulva the iguanas would become malnourished and weak. Many would die from disease and predation before they could die of hunger.)

- an upwelling occurred, bringing cold, mineral- and nutrient-rich water close to shore? (Algae thrive on mineral nutrients. An upwelling supports a growth in the numbers of phytoplankton and benthic algae (an algal bloom) so rapid that the clear, cold waters turn greenish. Algal blooms, in turn, promote a population explosion of herbivores, including filter feeders like bivalves and grazers like sea urchins. Many herbivores, like the bivalves and sea urchins, wear down reefs as they feed. Thus large reefs are not found in upwelling areas, despite the abundance of nutrients and food.)

- the anchovy population decreased? (Anchovies and other small fish provide food for seabirds. Birds that are able to fly, like the booby, could fly to other areas to find food. Birds unable to fly, like the penguin and the flightless cormorant, would be less able to reach new sources of food elsewhere.)

- ocean sea level changed? (Organisms adapt in different ways to the daily change in sea level. Some organisms, like barnacles, can close tightly so they don't dry up when the tide goes out. Other organisms, like ulva, grow below the tide line so that they are not exposed during low tides. In the Galápagos, two high tides and two low tides occur on an average day. Tidal amplitude is about 2.5 meters, more than 8 feet.

Over time, earthquakes in the Galápagos have uplifted coastal areas, and other forces have caused the islands to sink. In the Galápagos, the rate of sinking (or *subsidence*) is about 1 meter every 250 years. Subsidence is important to consider when projecting the survival of the stony reef-building corals. These corals must remain in the photic zone, the upper layer of the ocean where sunlight can penetrate, in order to survive. With island and surrounding seafloor sinking under them, the corals cannot survive unless they grow fast enough to keep up with the rate of subsidence and remain in the photic zone.)

5. Discuss how some organisms have adapted to the Galápagos.

- Make a class list of organisms that live on land, but are adapted to feed in the ocean. Challenge students to tell how each has adapted for feeding from the ocean. Possibilities include:

a. *flightless cormorant* - powerful swimming legs

b. *marine iguana* - uses its tail to swim in the water, turns head sideways; snout adapted for eating attached algae, claws adapted for grasping the algae

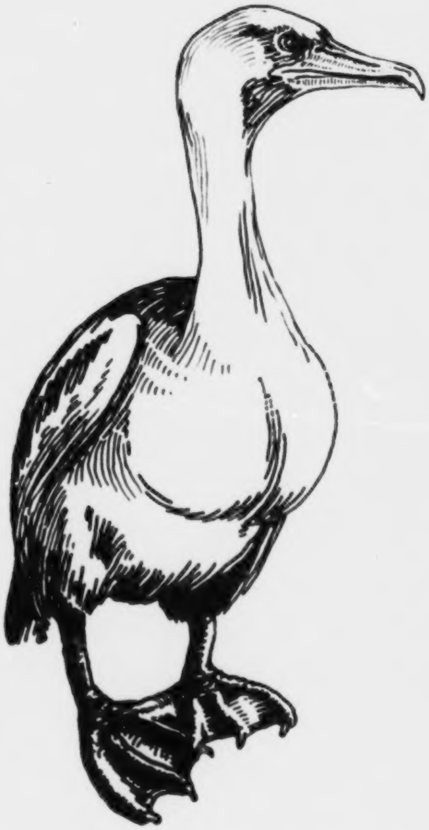
c. *penguin* - uses wings to swim in water; small compared to polar penguins, so needs less food

d. *turtle* - uses feet to paddle; snout shaped for eating seaweed

e. *booby* - good flyer, good vision; spots prey and swoops down to capture it

TEACHER TAKE NOTE

If your students have not already done Activity Two in Unit 3.5, Galápagos Iguanas, you may want to introduce it now.



6. Discuss the Galápagos sea lion and fur seal, two organisms that are usually found in temperate or subtropical waters. Ask students how they think these organisms have adapted to the warmer Galápagos climate. Specifically, ask them to think about how the animals might have changed their feeding habits. (The sea lions and fur seals that live in Antarctic waters must store warm layers of body fat. They can do this more easily than the animals in the Galápagos because food is generally more plentiful in cold waters than in warmer waters. With less stored fat, their Galápagos counterparts must eat often, so they more frequently enter the ocean to hunt food. Since ocean water temperature is cooler than daytime land temperature, their frequent forays into the ocean help keep the animals cool.

Milk from the Galápagos mothers contains less fat than milk from cold-water sea lions and fur seals. As a result, the Gálapagos pups develop more slowly and are dependent on their mothers for nutrients much longer than their colder-water counterparts.)

C. Conclusion

Ask students to predict the kinds of organisms that the Jason Jr. robot is likely to find.

(One way to approach this is to compare the nearshore organisms that live by eating attached seaweeds to the organisms that live by eating phytoplankton, tiny floating plants. Master 3.7a shows coastal-oceanic organisms to the left and oceanic (open water) organisms to the right.

Another approach could be based on predicted water conditions, particularly the presence or absence of upwelling.

Yet another approach is to use the information given on the back of Master 3.7a, Locations of Galápagos Organisms.

Discuss which organisms are likely to be scared away by the presence of the diver or the robot.)

Adaptations

For younger students

1. Make a bulletin board showing a marine food chain or food web in the Galápagos.

2. Make a drawing showing the seafoods commonly eaten. Be sure students understand that humans also belong to food chains.

3. Plan a tasting party.

For older students

1. Construct a bulletin board or diorama depicting:

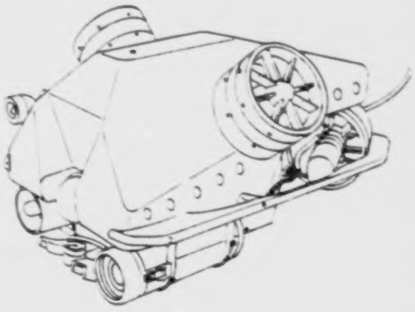
- organisms in a food chain drawn to scale or to true size.

- a coastal profile that shows the habitats of marine organisms by water depth. (Refer to Master 3.7b.) Decide with the students how to depict those animals that live on land but feed in the ocean. These include the marine iguana, boobies, cormorants, Galápagos penguins, frigate birds, fur seals, sea lions, and porpoises.

TEACHER TAKE NOTE

Begin with information provided in Master 3.7c. Use encyclopedias and other references to learn more about the organisms.

2. Debate the relative merits of humans and robots for exploring ocean environments. Consider the advantages and limitations of each. (The human diver is limited by air supply, water depth, and cold water temperatures. Nevertheless, he or she is a trained observer who is right there in the water—free to glance around, decide what and where to observe, then go there for detailed observations. Humans, especially trained and prepared humans like scientists, have far greater visual acuity than a remotely operated camera. A robot can stay underwater for very long periods of time and can freely explore in waters too deep for safe human diving. It must be operated, however, by people on the surface whose only view of the underwater is sent to them through the robot's video camera.)



For all ages

1. Find the names of at least five food items that contain seaweed or ingredients made from seaweed. (Japanese groceries and some other ethnic food stores sell seaweed in many forms, but snack foods, deserts, and other products found in every grocery store use algin and carrageen [made from algae] as thickeners and stabilizers.)

2. Collect favorite seafood recipes from your neighbors and families. Make a recipe book.

ACTIVITY TWO

New Kids on the Islands

Rationale

Some of the unique animals that live in the Galápagos are threatened by new species that have been introduced to the area. This lesson graphically demonstrates the impact of introduced species.

VOCABULARY

En•dem•ic spe•cies - a class of animals or plants that is native to a region, not introduced or merely resident.

VOCABULARY

Hab•i•tat - the natural environment that supports life.

In•tro•duced spe•cies - a class of animals or plants that is not native to a region, but has been brought in from outside and allowed to propagate.

Objectives

Students will:

Play the roles of goats and native species in an island ecosystem.

Describe how an introduced species could directly or indirectly affect an island's ecology.

Materials

- Transparency made from Master 3.7d, Introduced Species and their Distribution in the Galápagos Islands
- Overhead projector
- 30 meters of twine
- 20 paper plates
- 10 chairs

Procedure

Teacher Preparation

Make arrangements to use the gym or an outdoor playing field during the period when you will teach this lesson.

TEACHER TAKE NOTE

This activity may be unsuitable for senior high school classes. If you choose not to do it, you may wish to substitute Lesson 4.4 in the Social Studies Unit. See Note below.

A. Introduction

Explain to students that when a new type of living thing is brought into an ecosystem, it directly or indirectly affects all the other creatures in that system. Some of the species introduced into the Galápagos, such as cats and cattle, have had a neutral or even a positive impact. On many of the Galápagos Islands, however, packs of wild dogs have killed great numbers of young marine iguanas, sea birds, fur seals, and penguins—a direct negative impact on the endemic species. On some of the islands goats roam freely. They were introduced on Santiago as early as 1813 by the captain of a United States ship. On other islands, fishing expeditions and early settlers brought them in as a source of meat and milk. This activity will illustrate the impact of goats on the Galápagos ecosystem.

TEACHER TAKE NOTE

Lesson 4 in Unit 4 deals with the impact of another introduced species, the feral dog. Read that lesson as background for your teaching. If this topic holds particular interest for your students, you may want to do the lesson with them.

B. Lesson Development

1. Introduce the concept of habitat destruction as a threat to living things. Elicit from students' experience some examples of how people have changed the environment and eliminated species. (Paving prevents plant growth; draining marshes drives away waterfowl and fish.)

2. Project Master 3.7d and point out the distribution of introduced species throughout the Galápagos. Ask: What is there about islands, such as the Galápagos, that makes the impact of introduced species more severe than it would be, for example, in the mainland states of the United States? (Most of the creatures cannot easily move to another place to escape predators or damage to their habitat. Also, small islands frequently lack native predators that would otherwise control the population of the new species.)

3. Introduce an activity that illustrates the very specific habitat requirements of some species. Take the class to an open area such as the gym or the schoolyard. On the ground

or the gym floor, lay out 30 meters of twine to form a circle representing the island. Place ten chairs in the circle to represent vegetation, and ten paper plates on the ground inside it to represent the nests of ground finches. Explain that while some finches of the Galápagos nest in trees or bushes, several nests to one tree, ground finches build nests on the ground a meter or so away from each other.

4. Divide students into small groups of two or three. Hold out one student. Tell the rest of the class that they will represent finches of various species looking for nest sites. They should mingle around in the area for about 30 seconds. Sound a signal, at which time all the finches must find nests. A paper plate can only be occupied by one bird, but a "tree" (a chair) can house two or three. There should be enough nest sites for all students in this first round.

5. Demonstrate the impact of goats on the ecosystem:

- Blindfold the remaining student and explain that he or she will represent a goat. Tell the class that the goat was set free because the fishing boat on which it was riding was about to capsize in a storm.

- Direct the "goat" to walk slowly through the forest while the "finches" are out feeding. If the goat steps on a paper plate, that nest is destroyed. Remove the paper plate from the floor. If the goat encounters a chair, that "vegetation" is damaged and must be removed. After 30 seconds, remove the blindfold and discuss the damage done by the goat.

6. Begin round two of nesting with the same number of finches as in round one. Start the nest search with a signal to mingle. After 25-30 seconds, sound the signal again for birds to settle into a nest. Any birds that do not find a nest site must fly away from the area.

7. Repeat steps 4 and 5, but this time appoint one of the homeless finches to be a second goat. In subsequent rounds, double the number of goats each time. The simulation ends when all the vegetation has been removed.

C. Conclusion

Discuss the impact of goats on the finch population. Were any birds destroyed directly? (Young chicks in ground finch nests might be trampled, but direct impacts are few.) How did the goats *indirectly* impact the finches? (by destroying nests and nest sites)

Expedition Review

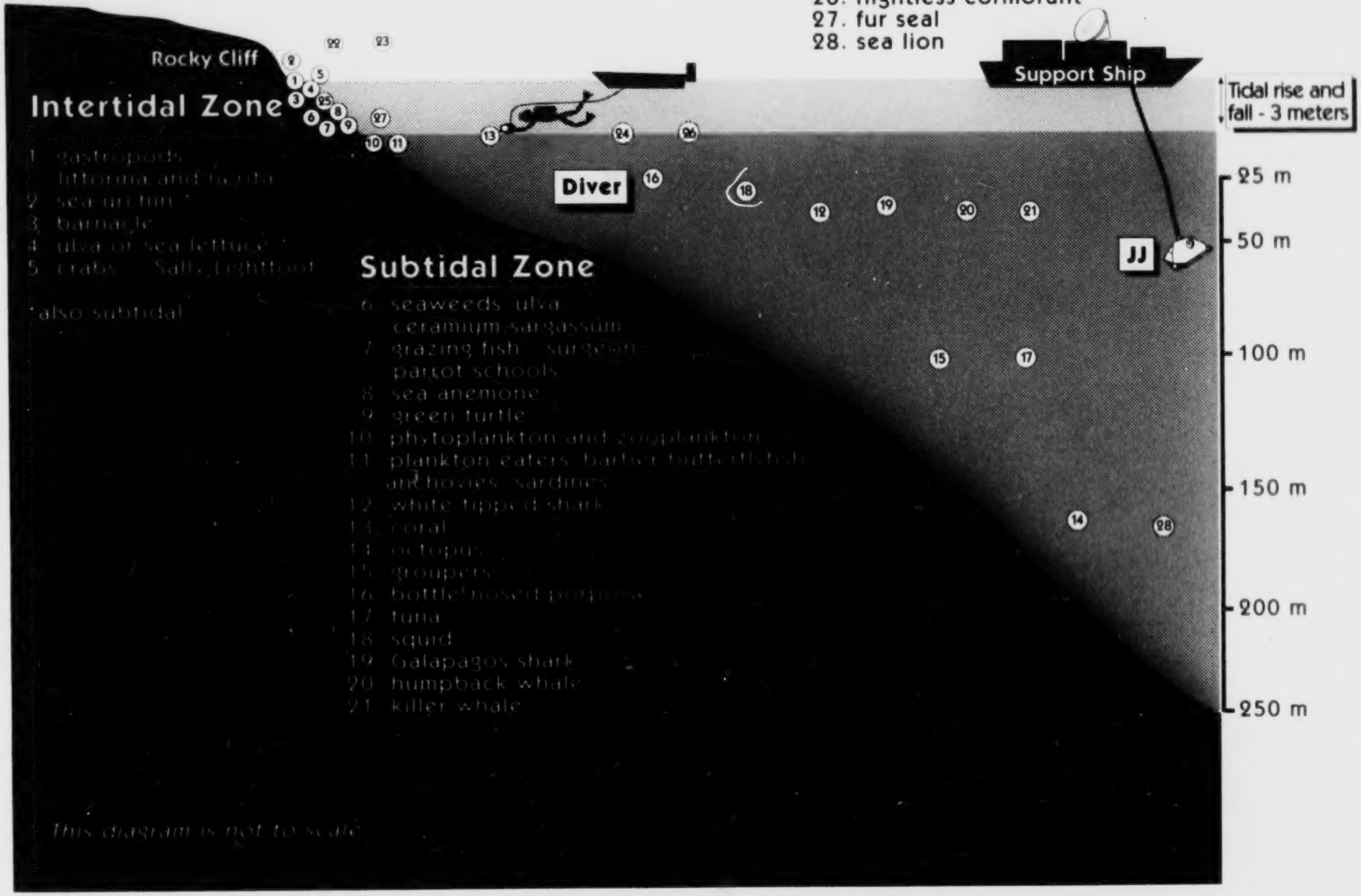
Review the concepts of endemic species versus resident and introduced species. Cue the students to try to classify each animal they see during the downlinking into one of these groups.

Location of Galápagos Marine Organisms

The numbers on this chart show the maximum depths at which the listed species can be found. The diver and JJ are shown at their Galápagos operating depths.

Ocean Feeders

22. booby
23. frigate bird
24. marine iguana
25. Galápagos penguin
26. flightless cormorant
27. fur seal
28. sea lion


Rocky Cliff
Support Ship
Tidal rise and fall - 3 meters
Diver
JJ
25 m
50 m
100 m
150 m
200 m
250 m
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

Intertidal Zone

1 gastropods
littorina and fissurella
2 sea urchin *
3 barnacle
4 ulva or sea lettuce *
5 crabs — Sally Lightfoot

*also subtidal

Subtidal Zone

6 seaweeds: ulva
ceramium, sargassum
7 grazing fish — surgeon,
parrot schools
8 sea anemone
9 green turtle
10 phytoplankton and zooplankton
11 plankton eaters: barber butterflyfish,
anchovies, sardines
12 white tipped shark
13 coral
14 octopus
15 groupers
16 bottle-nosed porpoise
17 tuna
18 squid
19 Galapagos shark
20 humpback whale
21 killer whale

This diagram is not to scale.

Back of Master 3.7a
Locations of Galápagos Organisms

Dr. Wellington's Dive

Jerry Wellington, the JASON scuba diver, will be diving to depths of about 6-16 m (20 to 53 feet). He will see coastal animals that obtain their food along the rocky shoreline and in the shallow waters just off Fernandina Island. Some of these animals, like the marine iguanas, penguins, and sea birds, live and breed on the rocky cliffs and shorelines, but go into the ocean to feed. The animals that Jerry is most likely to see are those fish and other swimming organisms that live permanently in the shallow coastal waters, and the marine plants and animals, like sea stars, octopus, and corals, that live on the shallow ocean floor. Jerry may also see some oceanic organisms, like tuna—and perhaps a whale or a large shark—that swim into the shallow coastal waters to feed.

From his base near the shore, Jerry Wellington will also be able to see and report on the plants and animals that live permanently at the water's edge. Examples of these are the Sally Lightfoot crabs and other shellfish that live on the wave-pounded rocky outcroppings. These shellfish in turn are important sources of food for many larger organisms living in the coastal waters.

JJ's Dive

The robot Jason Jr. (JJ) will be diving deeper than the scuba diver will go, to depths of 30 to 50 meters (about 98 to 164 feet down). At these depths, so little sunlight penetrates the water that few marine plants can grow, so JJ is unlikely to find an abundance of marine plants or animals that feed on plants. Nevertheless, the waters will be full of life. Undoubtedly, the robot will encounter some of the large fish that swim up into shallower waters to feed upon the smaller fish that Jerry sees.

The deep waters the robot explores will be colder than the shallow water where the diver makes his observations. The robot, then, should "see" organisms that live in cold water.

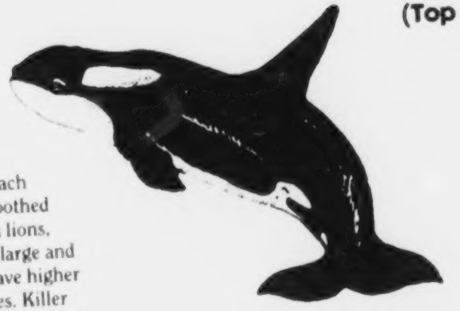
Water Conditions

The ocean waters that surround the Galápagos are normally clear, allowing for good underwater visibility. If an upwelling is occurring, however, the cold nutrient-rich waters that flow upwards into shallower waters may spur a plankton bloom, a sudden explosive increase in the population of phytoplankton, microscopic algae, and zooplankton, the tiny animals that feed on phytoplankton. In just a few days a plankton bloom can cloud the water, tinting it shades of green or brown. Viewing will be hampered under these conditions.

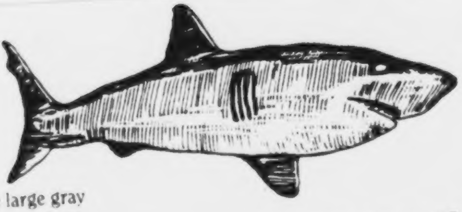
Galápagos Marine Organisms

MASTER 3.7b

Trophic Level 6. (Top Carnivores)

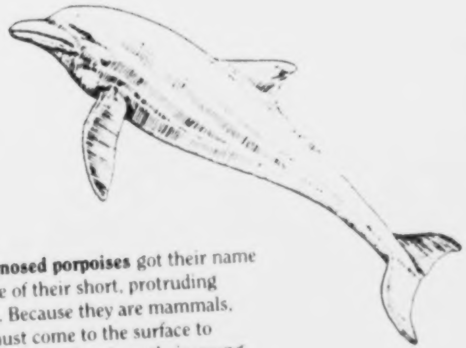


Killer whales (*Orcus*) can reach lengths of 6.5 m. They are toothed whales that eat fur seals, sea lions, bottle-nosed porpoises, and large and medium-sized fish. Males have higher dorsal (top) fins than females. Killer whales have no natural enemies. Their population size is limited by disease and food supply.

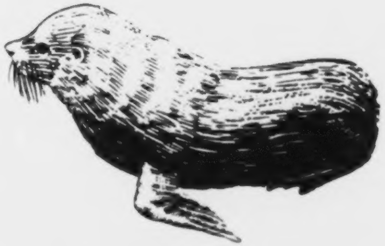


Galápagos sharks are large gray sharks with distinctive uniform coloration. They reach 3 to 4 m (10-13 ft.) in length. Active swimmers, they are usually found patrolling for food in water from 1-17 m (to 56 ft.) just seaward of dropoffs. Their triangular upper teeth are sharp and serrated like steak knives. To satisfy their large appetites, they eat medium to large-sized fish, and not infrequently take bites out of sea lions and turtles. When human divers are in the water they are very curious, and approach them at close range, but they are not usually aggressive toward humans. A large adult shark can be twice the size of a human diver. Other large sharks, including cannibalistic Galápagos sharks, prey upon them.

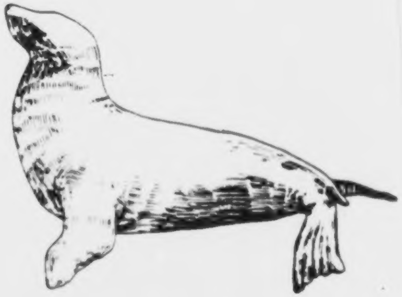
Trophic Level 5.



Bottle-nosed porpoises got their name because of their short, protruding snouts. Because they are mammals, they must come to the surface to breathe in air. They bear their young live and nurse them for about a year. They are sociable animals, travelling in pods with about six other porpoises. Adults grow to approximately 2.5 m (8 ft.), and feed on fish and squid. Their streamlined bodies allow them to swim at about 10 knots (around 12 mph), darting in short bursts of speed to almost 20 knots (23 mph). Killer whales prey upon these porpoises.



Fur seals found in the Galápagos are the smallest of all known species. Adult males grow to over 2.5 m (8 ft.) and weigh about 70 kg (154 lbs). Females are smaller, averaging about 35 kg (77 lbs). They live in colonies on rocks with shaded overhangs that protect them from the daytime sun. There they breed and give birth. At night they feed offshore, diving to about 30 m (100 ft.) to catch fish and squid. They are eaten by larger sharks and the killer whale.



Sea lions are larger than fur seals, growing to almost 3 m (nearly 10 ft.). They live on the beach, but give birth in the ocean. They spend their days in the water to stay cool. They feed both day and night, diving to depths of 200 m (656 ft.) to catch fish. Adults are aggressive toward humans, but juveniles are playful and curious. Large sharks and the killer whale prey upon them.

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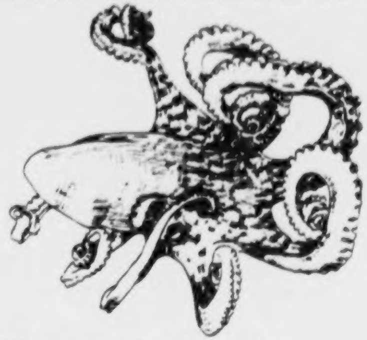
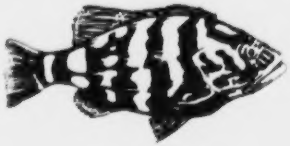
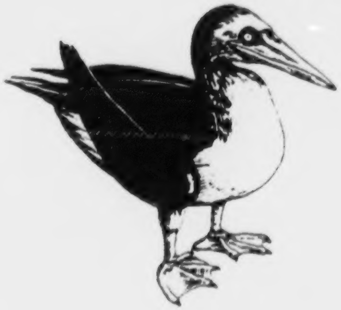
Trophic Level 4



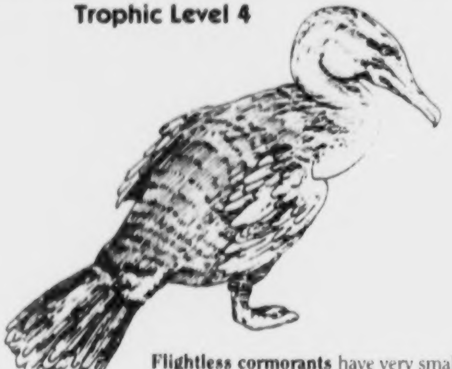
Octopuses are bottom dwellers that grow in the Galápagos to about 30 cm in length. They are very intelligent, but shy. They can change color quickly, so they blend into the background and are hard to see. Their untidy dens are easy to locate, however, because of the empty seashells they leave strewn about. They eat small fish and shellfish. Octopuses are eaten by the predatory fish found in this trophic level.



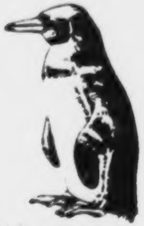
Groupers can grow to a meter or more in length. They prey upon small and medium-sized fish and upon crustaceans (shrimp and lobsters). Their depth range is from 3-30 m. Groupers are eaten by sharks.



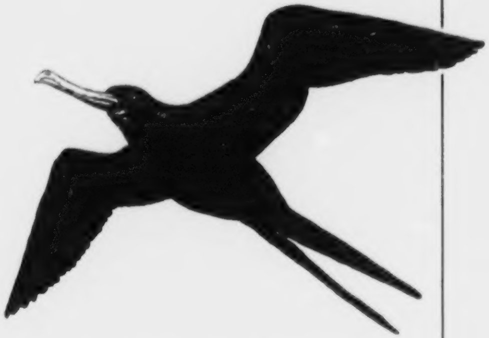
Blue-footed boobies are excellent flyers that feed on fish from the nearshore waters to a few miles offshore. They frequently catch fish by folding their wings and diving down into the ocean from great heights. Their nests are on land. A baby chick feeds by inserting its sharp-pointed bill down into its parent's throat to obtain partially digested fish. Hawks prey upon the chicks. When offshore fish are scarce, many young chicks die from lack of food. The adults are harassed by the frigate bird, which tries to steal their fish.



Flightless cormorants have very small wings, but they have thick, muscular legs adapted for swimming. They chase and catch small schooling fish that live within 10 to 15 m from shore. Like the boobies, they nest on land, and hawks prey upon their chicks also. If the adult cormorants cannot find enough food, their chicks die. Sharks prey upon the adults.



Galápagos penguins, which grow to about 36 cm tall, nest in holes along the shoreline. They cannot fly in the air, but appear to fly in the water, using their greatly-modified wings like paddles. Their swift underwater swimming allows them to catch small schooling fish from both nearshore and offshore waters. Food supply controls the population of penguins in the Galápagos. When schooling fish are scarce, juvenile penguins cannot survive.



Frigate birds when fully grown are about 110 cm long, and their wing span is about 210 cm, but they only weigh a little over 1 kg. The frigate bird can use its long, pointed wings and forked tail to make sharp spiral turns and dive at great speeds through the air. The male is entirely black; the female has white feathers on its breast and upper throat. Because of their habit of stealing fish caught by boobies and other birds, these graceful birds are sometimes described as parasites. They occasionally do their own fishing, however. Their population size is controlled by food supply.

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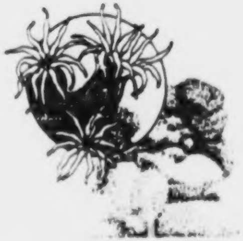
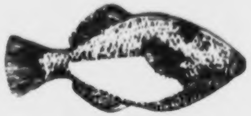
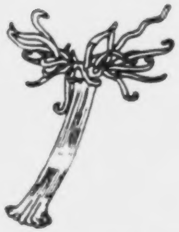
Trophic Level 3



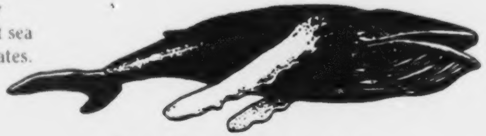
Coral polyps, animals that look like tiny sea anemones, secrete a hard, calcareous skeleton. Coral reefs are made up of colonies of corals. In the Galápagos a coral head can be as small as a golf ball or as large as a house. Coral polyps use their tentacles to reach out and capture zooplankton for food. Symbiotic algae, called ***Zooxanthellae***, live in the tissue of the polyps, and benefit the coral by producing additional food as well as oxygen for the polyps to use. One type of sea urchin and a number of fish feed upon the coral polyps.



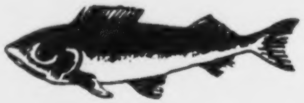
Triggerfish, typically found in depths from 1 to 18 m (3-59 ft.), have characteristic prominent spines. When a triggerfish is chased into a hole by a larger predatory fish, it opens its spines to wedge itself in place. The open spines not only make it difficult for the predator to dislodge the triggerfish, but also make the prey painful to swallow. Triggerfish eat sea urchins and other small invertebrates.



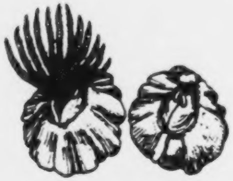
Sea anemones are entirely soft-bodied animals that attach themselves to rocks. They resemble flowers or miniature palm trees because of the circle of waving tentacles that surrounds their central stalk. They are active carnivores, however, and wave their tentacles purposefully to capture zooplankton. Fully extended, they reach 6 cm in height and 3 cm (a little more than an inch) in diameter. Marine snails feed on them.



Humpback whales are toothless baleen whales. They gulp in huge quantities of seawater, using baleen plates in their mouths to strain out plankton, small fish, and other small organisms for food. Humpbacks winter in subtropical waters, where they breed, and summer in cooler waters. They prefer coastal waters and shallow banks. When they travel from summer to winter grounds, they swim in herds led by a large male. The humpback has a characteristic long, white flipper. It can grow to 15 m (50 ft.) in length and weigh up to 51 tonnes (46 tons). The killer whale is its natural enemy, preying on its young.



Anchovies and **sardines** are small fish that normally live in the open ocean. They feed on zooplankton. When the zooplankton drift close to shore, these fish follow their food into shallow waters. Anchovies and sardines are food for tuna, penguins, and boobies.



Barnacles live tightly cemented to rocks on wave-pounded shores. They range from 1 to 3 cm (an inch or less) in diameter. Their hard outer shell is made up of overlapping calcium plates around a central opening. The opening can be closed tightly to protect their soft inner parts. Barnacles feed by extending appendages out of their shell and waving them about to trap small animals and fragments of food. They filter zooplankton and small food particles from the water. Predatory gastropods (marine snails) and birds such as the oyster catcher prey on them.

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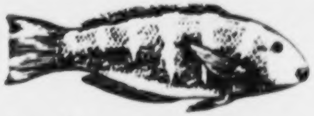
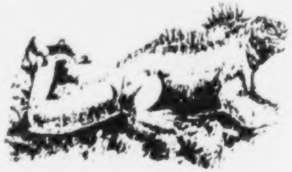
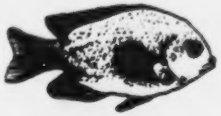
Trophic Level 2 (Herbivores)



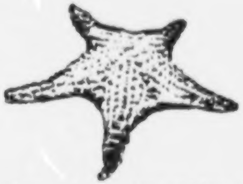
Parrotfish (up to 1 m in length), so named because of their blue-green color and parrotlike beak, use their beaks to bite off and crush chunks of coral from the reef. They are considered herbivorous because they digest the algae coating on the coral, passing the broken remains of the coral through their digestive systems. Despite their powerful beaks, they are gentle fish and creatures of habit that swim along set feeding routes. They are food for even larger predatory fish.



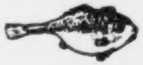
Marine iguanas live on the rocky shores, but dive in the nearshore waters to depths of about 10 m (33 ft.) to dine on the green seaweed ulva. When ulva became scarce after the El Niño event, the marine iguanas tried eating ceramia. Many iguanas starved because ceramia did not fulfill their nutritional needs. Galápagos hawks prey upon marine iguanas on land and occasionally sharks eat them as well.



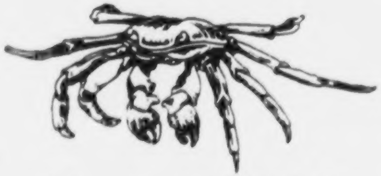
Damselfish (7-25 cm in length) are sometimes described as "algal gardeners" because of the way they stake out and defend their home territories. The males chase away other herbivorous fish, including other damselfish. They also pick up herbivorous sea urchins and move them away from the algal mats. Larger fish and seabirds prey on damselfish.



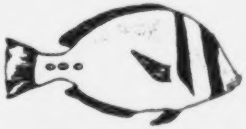
Sea stars and spiny **sea urchins**, close relatives to the crab, move about in large numbers over the submerged rocks and corals, searching for attached algae to eat. The sea stars have five rays (arms) arranged around a central mouth that is located on the underside. Tube feet help them hold onto rocks and move about in the water. Calcareous algae are their preferred food. Sea urchins have thick spines encasing and protecting their bodies. Like the sea stars, they have mouths on the underside and tube feet. Both are eaten by predatory fish such as **wrasses** and **triggerfish**.



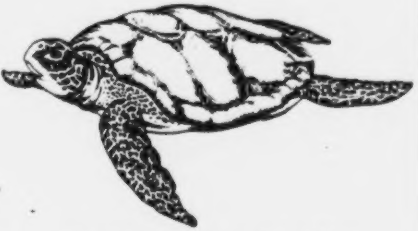
Zooplankton are animals that float or swim very weakly. Some zooplankton, like the **copepods** and **jellyfish**, remain as floating plankton all their lives. Others, like the tiny larvae of fish, eventually outgrow their early planktonic stage. As they drift around, the zooplankton feed on phytoplankton.



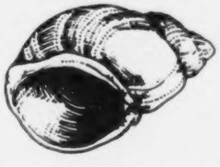
Crabs, nicknamed "Sally Lightfoots" because of their speed and agility, live on shoreline rocks both above water and to depths of about 1 meter. Their flat bodies are well adapted to living in a high wave area. These crabs feed on algae. They are eaten by birds and fish. Adults are bright red, but the black color of the juveniles provides them somewhat greater protection from predators.



Surgeonfish (25 cm in length), notable for their beautiful color, have one or two sharp spines on their sides. They swim together in small schools, aggressively chasing other herbivorous fish away from their territory. They feed on algae within a set area. Predatory fish eat them.



Green sea turtles are air-breathing reptiles that come ashore to reproduce, but spend most of their lives at sea. They feed in shallow coastal waters, foraging for ulva. They sometimes migrate great distances in search of ulva beds. Like marine iguanas, green turtles starved when the ulva became scarce after the El Niño event. Sharks prey upon the green turtles.



Nerita (about 2 cm) distinguished by its round shell, remains wet most of the time, living in the zone just below the Littorina. Nerita are usually found in groups under ledges or in depressions in the rock. Hermit crabs may live in nerita shells. Both littorina and nerita are eaten by birds such as the heron.

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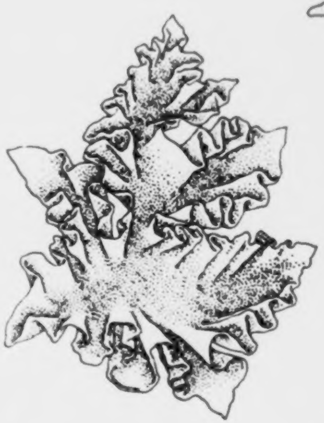
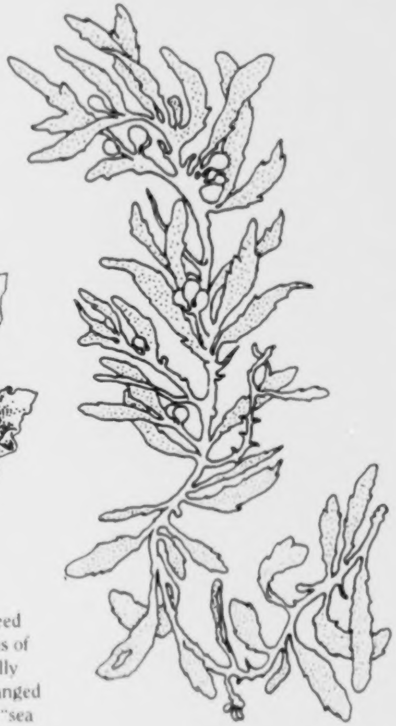
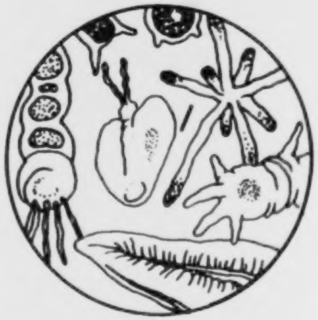
Trophic Level 1



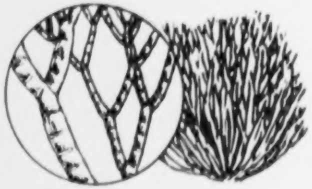
Ulva is a fast-growing green seaweed found from the shoreline to depths of about 8-10 m (26-32 ft.). When fully grown, ulva looks like loosely arranged lettuce leaves, so it is often called "sea lettuce." It is the favorite food of the marine iguana and an important food for turtles, as well as for damselfish and many other herbivorous fish. Thus ulva is usually found in the Galápagos looking more like mowed grass than like lettuce. The herbivores keep it cropped to about 2 cm. Warm water and a lack of nutrients during the El Niño almost wiped out the ulva population, depriving many herbivores of their primary food.



Sargassum is a brown seaweed averaging about 15 cm (6 in.) in length. It has characteristic air sacs that support it in the water. Although it is abundant, it is not eaten by many organisms because it contains toxic substances.



Phytoplankton are the very abundant, but minute (less than 1 mm, or 0.039 in.) algae and plantlike organisms that drift in the ocean. Phytoplankton include the dinoflagellates, coccolithophores, diatoms, silioflagellates, and blue-green algae. These live near the surface, using sunlight, carbon dioxide, and water to produce food and oxygen. When they are deprived of nutrients, however, as they were in the El Niño years, their numbers decrease. Phytoplankton provide food for zooplankton.



Ceramium is a small (.5 cm) filamentous red alga found in waters to about 50 m (164 ft.) deep. It provides food for damselfish, surgeonfish, parrotfish, some sea stars, and snails. When the ulva was almost wiped out by El Niño, the marine iguanas starting eating ceramia, but these red algae do not provide all the nutrients the iguanas need.

MASTER
3.7c

Trophic Levels of Galápagos Organisms

Trophic Level 6 (Top Carnivores)

- Galápagos sharks
- Killer whales

Trophic Level 5

- Fur seals
- Sea lions
- White-tipped sharks
- Bottle-nosed porpoises

Trophic Level 4

- Blue-footed boobies
- Flightless cormorants
- Galápagos penguins
- Frigate birds
- Octopus
- Groupers
- Tuna
- Squid

Trophic Level 3

- Barnacles
- Sea anemones
- Coral polyps
- *Zooxanthellae*
- Butterflyfish
- Wrasses
- Triggerfish
- Anchovies
- Sardines
- Humpback whales

Trophic Level 2 (Herbivores)

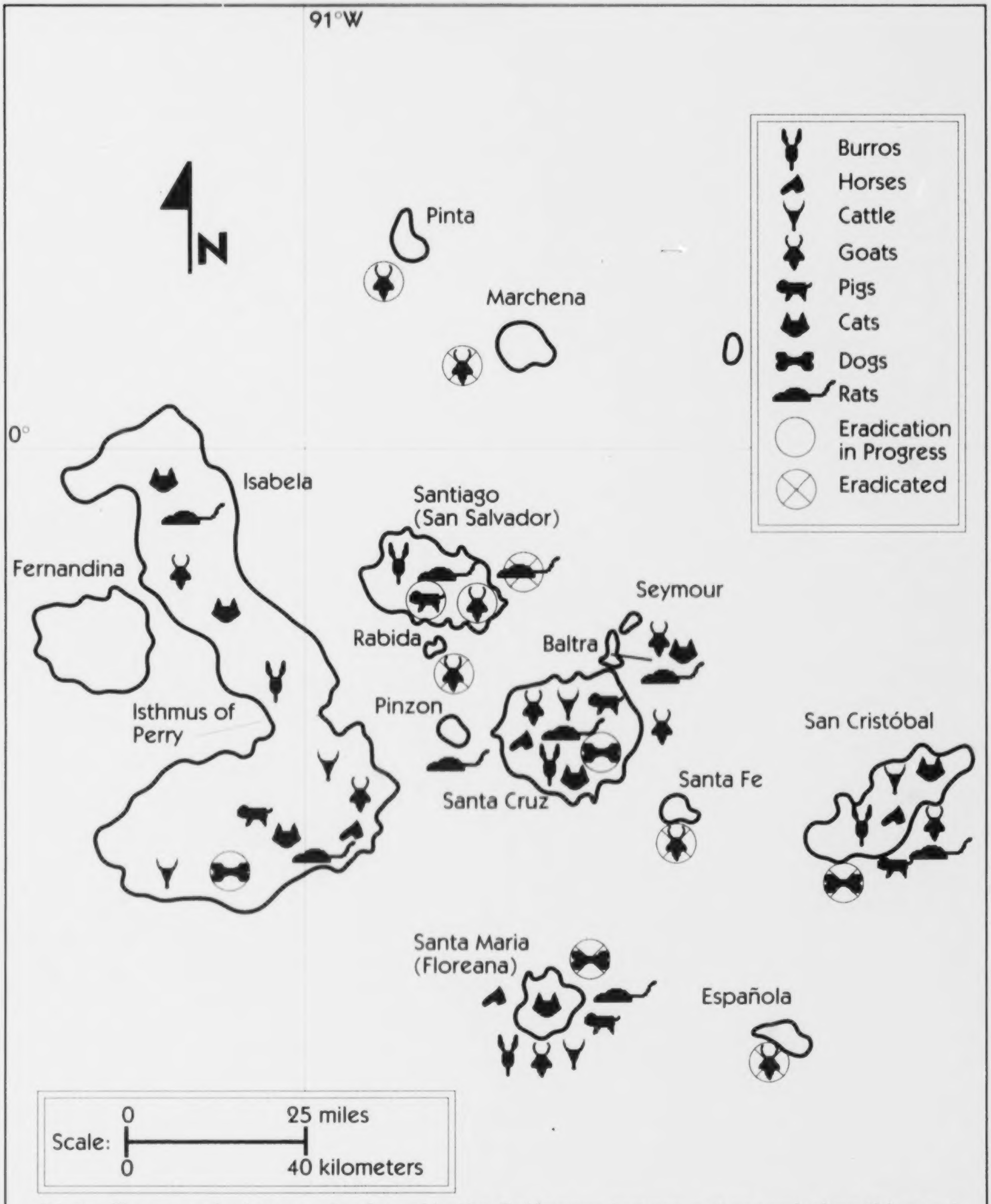
- Zooplankton
  - Copepods
  - Jellyfish
- Herbivorous shellfish
  - *Littorina*
  - *Nerita*
- Sally Lightfoot crabs
- Sea stars
- Sea urchins
- Herbivorous fish
  - Damselfish
  - Surgeonfish
  - Parrotfish
- Marine iguanas
- Green sea turtles

Trophic Level 1 (Primary Producers)

- Phytoplankton
  - Blue-green algae
- Seaweeds (marine algae)
  - *Ulva*
  - *Sargassum*
  - *Ceramium*
- Calcareous algae

MASTER
3.7d

Introduced Mammals and their Distribution on the Galápagos Islands


91°W
0°
N
Pinta
Marchena
Isabela
Fernandina
Santiago
(San Salvador)
Seymour
Rabida
Baltra
Pinzon
Isthmus of
Perry
Santa Cruz
Santa Fe
San Cristóbal
Santa Maria
(Floreana)
Española
Burros
Horses
Cattle
Goats
Pigs
Cats
Dogs
Rats
Eradication in Progress
Eradicated
Scale:
0
25 miles
0
40 kilometers

(Note: Sheep and mice are also found in the Galápagos but are not recorded on this map)

THE GOOD NEWS AND THE BAD NEWS: BIOLOGICAL IMPACT OF EL NIÑO

3.8

ACTIVITY ONE

Records in the Rings

Rationale

The El Niño event of 1982–83 changed the living conditions of organisms in the Galápagos. The bodies of some organisms preserved a record of their response to those changes in terms of growth.

Objectives

Students will:

Observe that the body parts of some organisms contain a record of their growth patterns.

Interpret tree rings and tortoise shell scutes to determine how environmental conditions have affected the growth of these organisms.

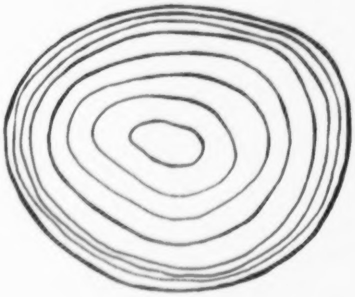
VOCABULARY

Prox•y - A person or thing that substitutes for another.

Scutes - External bony or horny plates, such as those that cover a turtle's shell.

Materials

- "Wood cookies" (cross sections of tree trunks), at least one for every two students
- Student copies of Master 3.8a, Interpreting Growth Rings
- Pencils and paper for sketching



Procedure

Teacher Preparation

Before you do this activity, collect 6–8 cm slices of tree trunk ("wood cookies") from a place where trees have recently been cut. Evergreen trees are easy to cut and usually have very distinct rings. Do not get all the cookies from the same tree—the more trees the better, so that a variety of ring patterns is observable.

TEACHER TAKE NOTE

The school shop or a local lumber yard may have large timbers (4x4 or 6x6) that can be cut into short lengths to serve as tree cookies. Avoid slices that have been cut at the point where the branches come out of the trunk. Because the wood is hard to cut at this point, the pattern of the tree rings may be interrupted.

A. Introduction

Explain that scientists sometimes use what they call *proxy data* to study things they cannot observe directly. They study ice cores from Antarctic glaciers, for example, to gain information about the amount of carbon dioxide that was in the atmosphere several centuries ago. When huge old trees are cut down, their stumps reveal growing conditions over the years of their lives.

B. Lesson Development

1. Discuss the concept of proxy data and how it can be used to study past environmental conditions. Distinguish the use of

proxies from simulations, such as the Natural Selection Activity in Lesson 3.7.

2. Distribute a wood cookie and a copy of Master 3.8a, Interpreting Growth Rings, to each team of two students. Instruct each team to exchange with another team after they have sketched their own cookie, so everyone has a chance to see two different ring patterns.

3. Direct students' attention to the tortoise scutes sketched on the same master. Explain that even related organisms may react very differently to the same environmental conditions. During the 1982–83 El Niño, giant tortoises and green sea turtles both had to live in a warmer environment than they had ever known before. The tortoises thrived. Sea turtles, however, suffered in warmer water.

Explain that the growth of a sea turtle isn't visible in the scutes, but can be studied in a cross section of its largest bones. Have students study the tortoise scutes and then hypothesize what a sea turtle bone would look like for the same period. (The 1983 ring on the bone may be very thin or may not exist at all.)

C. Conclusion

Challenge students to think of other organisms that record their growth patterns in their own structure. (Examples might include fish scales, hailstones, sea shells, and ferromanganese nodules. Ask: How is proxy data important to the scientist? (The scientist cannot be everywhere, and data have not been recorded forever. The use of proxy data allows scientists to make inferences about things that happened far away and long ago.)

ACTIVITY TWO
It's an Ill Wind That Blows No Good

Rationale

The El Niño event of 1982–83 changed living conditions for animals in the Galápagos. For some animals conditions improved. Others suffered from the changes.

Objectives

Students will:

List the environmental changes during El Niño that affected Galápagos animals.

Identify the positive and negative effects of El Niño on a given list of organisms.

Cooperatively generate a class data chart.

VOCABULARY

Fledg•ing - in young birds, the development of the wing feathers that precedes flight.

Hatch•lings - the newly hatched young of egg-laying species.

Pho•to•syn•the•sis - the process by which green plants combine water and carbon dioxide in the presence of sunlight to make sugar and oxygen.

Pre•da•tion - a mode of life in which food is obtained primarily by killing and eating other organisms.

Sym•bi•o•sis - a close interrelationship between two different organisms that may be, but is not necessarily, of benefit to each.

Materials

- Student copies of Master 3.8b, Impact of El Niño (2 pages: Birds and Corals; Marine Mammals and Reptiles)
- Student copies of Master 3.5e, Some Land Animals of the Galápagos Islands, and Master 3.7b, Galápagos Marine Organisms (one set for each small group unless students already have the masters in their JASON journals)
- Writing materials for group notes
- Poster board or chalkboard for class data chart
- Markers or chalk

Procedure

Teacher Preparation

Cut the copies of Master 3.8b in half to make two cards out of each sheet.

A. Introduction

Challenge students to explain the proverb in the title of this activity. The old saying points out that even in what is generally perceived as a disaster, some people (or organisms) are likely to thrive; it's an ill wind indeed that blows no good to anyone. The animals of the Galápagos responded differently to the changes in their environment during El Niño. The dramatic changes were harmful to some species, but beneficial to others.

If students do not have Master 3.5e, Some Land Animals of the Galápagos Islands, and Master 3.7b, Galápagos Marine Organisms, in their JASON journals, give one set to each small group.

B. Lesson Development

1. Ask students to count off by fours, and assign each to an expert group. All the 1s will be bird experts, the 2s coral experts, the 3s mammal experts, and the 4s reptile experts. Explain that after the students become expert about the impact of El Niño on their animal group, they will teach another group what they have learned.

TEACHER TAKE NOTE

The reading level of the impact cards will be difficult for elementary students. You may wish to begin by reading the cards aloud to each expert group.

2. Give each student an impact card for the animal group to which he or she is assigned. Ask students to gather in their expert groups for about ten minutes and read the material on their cards. They will also consult the masters, read about the animals in their own category, discuss, and take notes.

3. At the end of the work period, form new cooperative groups of four that contain one representative of each of the four animal groups. Use the numbers originally assigned to designate roles within the new group. Each student will have a responsibility in addition to reporting from his or her original group.

- Discussion leader (1, bird expert): calls for the representative of each animal group to report on what the group has learned; prevents interruptions and encourages attention.

- Recorder (2, coral expert): writes down the group's report on El Niño environmental changes and animal responses to them.

TEACHER TAKE NOTE

Group data sheets will not be handed in, so they only need to be neat enough for students to read.

- Coordinator (3, mammal expert): makes sure each group member contributes and the group's work is completed on time.

- Checker (4, reptile expert): makes sure each team member agrees with what is being written down; gets teacher feedback, if necessary.

4. As each team member reports from the perspective of his or her expert group about the impact of El Niño on specific animals, the other students will take notes. When all members of the group are satisfied that the information is complete, the group will assemble one data sheet, listing effects on all four groups of animals.

C. Conclusion

Make four columns on the poster board or chalkboard. Ask each group to supply data on one of the four animal groups. (By this time they should all be experts on all the groups.) When all have reported, students from other groups can fill in anything that has been left out. Discuss any areas that caused differences of opinion. Emphasize the range of animal reactions to El Niño, even within groups. Ask:

- Overall, does it appear that El Niño was a positive or a negative influence on the animals of the Galápagos? (negative)

- What do you think the long-term effects may have been, for the animals mentioned on the impact cards and for others that were not? Allow students to speculate. (The burro population, for one example, increased rapidly after El Niño because of the increased supply of vegetation. When conditions returned to normal, many burros starved to death.)

Adaptations

For younger students

Unless they are used to working in cooperative groups, younger students will need more guidance from the teacher than these instructions specify.

For older students

1. The teacher's role may be quite minimal. Groups may exchange notes for fact checking, for example, rather than requiring the teacher's approval.

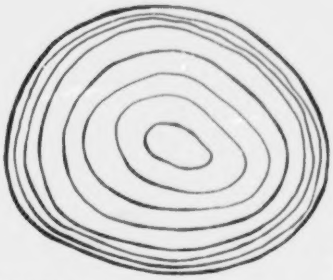
2. You may want to bring additional reference materials into the classroom, or assign students to read the articles on which the impact cards were based, listed in the bibliography for Unit 3. Give students full data for these readings and encourage them to find others.

Expedition Review

If you made your class data chart on poster board, save it and use it to remind students of how living conditions changed with El Niño, and how the animals responded to it.

MASTER 3.8a

Interpreting Growth Rings



Wood Cooky

1. Sketch the patterns of several cookies on the back of this sheet.
2. If each ring represents a year of growth, what does the pattern of the rings suggest about each tree's development?

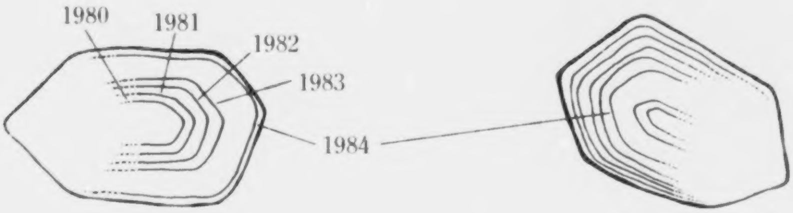
Tortoise Scutes

Like a tree, a tortoise's shell grows from the inside out. The first scute below is labeled to show when each ring was laid down.

- What happened in 1983?
- How did this event affect the tortoise?

Interpret the second scute. Label the years of growth.

- How could you tell which year was 1983?
- What has the weather been like since then?



Green Sea Turtle Bone

Sea turtles had to live and feed in unusually warm water during El Niño. These conditions did not favor their growth. The circle represents a cross section of a bone from a sea turtle born in 1980. Draw rings to indicate its growth pattern, and label the years.

-Why did El Niño affect the sea turtles so severely?

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Back of Master 3.8a
Answer Sheet

Wood Cooky

1. Sketch the patterns of several cookies on the back of this sheet.
2. If each ring represents a year of growth, what does the pattern of the rings suggest about each tree's development?

Trees grow at different rates from year to year depending on weather. One year a tree may increase its diameter less than one centimeter, and the next year it may increase by several centimeters.

Tortoise Scutes

Like a tree, a tortoise's shell grows from the inside out. The first scute below is labeled to show when each ring was laid down.

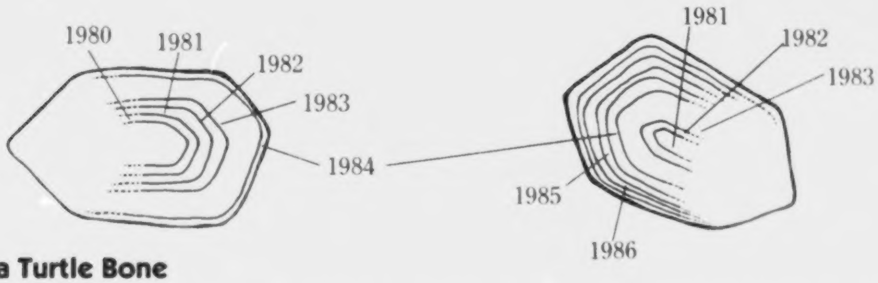
- What happened in 1983? **El Niño occurred in 1983, bringing warm water and rain to the Galápagos area.**

- How did this event affect the tortoise? **Increased rainfall caused land plants to flourish, providing extra food for tortoises and other land dwellers.**

Interpret the second scute. Label the years of growth.

- How could you tell which year was 1983? **It is the widest ring, indicating most growth.**

- What has the weather been like since then? **The temperatures have been cooler since 1983.**



Green Sea Turtle Bone

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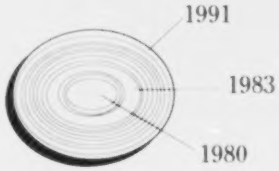


-Why did El Niño affect the sea turtles so severely?

Warm water and rough seas destroyed the seaweeds that the turtles live on so they and their young starved.

Impact of El Niño

MASTER
3.8b

Birds

The effects of El Niño on birds depended greatly on whether or not they could migrate. Species that rely on the ocean for food were also affected differently from those that find their food on land. Breeding populations of blue-footed and masked boobies on some islands were greatly reduced. On Isla Daphne Major, observers counted 348 masked booby pairs in 1982, but only 135 in early 1984. This was apparently the result of increased rainfall and higher temperatures, which encouraged the growth of plants on the crater floor. Masked boobies build their nests on bare ground, and the plants used up the available nesting space.

The boobies' food supply was also affected, since the productivity of the oceans fell and the fish population changed. Many of the birds left the Galápagos Islands and migrated to other locations in search of food. Most of those who remained did not breed. For those that did breed, the clutch of eggs was smaller than usual.

Darwin's finches, on the other hand, had a great year. High rainfall made small seeds and caterpillars, the finches' main foods, more plentiful. Some birds bred ten times in the season, and some young birds that hatched at the beginning of the season were mating before the season was over.

The large number of young produced quadrupled the population on one island. The long-term consequences of this increase are still being determined.

Corals

Coral polyps contain within their living cells a type of algae, called *Zooxanthellae*, that color the polyps golden brown. The coral and algae live in symbiosis, each benefiting the other. The corals provide a home for the algae, along with carbon dioxide for carrying out photosynthesis and nitrogen that helps the algae grow. The algae provide food and oxygen for the coral animals and speed up the skeletal growth of the coral colony.

For a coral reef to thrive, the corals and their symbiotic algae must remain entirely underwater with little change in the temperature or the saltiness of the water. Galápagos corals thrive in water that ranges from18-25° C. Whenever the water temperature stays too high for too long, corals lose their *Zooxanthellae* and bleach, or turn pale. Without the algae, the corals grow more slowly and eventually die. When El Niño raised water temperatures to 30-31° C for four to five months, large numbers of corals bleached and died.

Although the temperature increase was the most important factor, the excessive rains and storm surges that accompanied El Niño also disturbed the corals. High rains dumped large quantities of fresh water, flooding the coastal waters and making their upper level less salty than usual. As the El Niño waves rolled by the Galápagos, sea level dropped about 4.4 cm, leaving some of the coral colonies high and dry.

Coral reefs have been known to recover from natural

2 16

Birds

During a five-year study of petrels, researchers found that chick growth was slower during El Niño than during normal years. There was less for the birds to eat because ocean plant production was down and other food supplies were greatly reduced. The scientists concluded that the late fledging and slow growth was a way for the birds to save energy.

Many other marine birds were unable to lay eggs, lost their young, or starved because the fish they were accustomed to eating were no longer available. Some of the affected species were the flightless cormorant, Galápagos penguin, waved albatross, and common frigate bird.

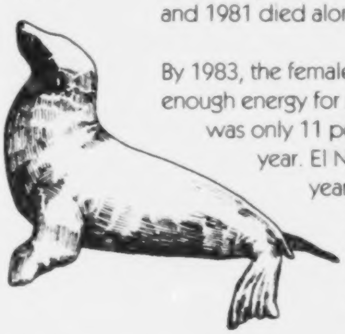
Researchers studied birds migrating through the islands during the period of high winds and rains. Black terns were observed in the Galápagos for the first time, as were rosebreasted grosbeaks and eared doves. The scientists hypothesized that El Niño disrupted migration routes. Severe weather and unusual wind directions also redistributed birds from one island to another. Some, but not all of these species may turn out to be long-term residents. These changes give scientists an opportunity to reconstruct how the ancestors of some of the islands' unique species may originally have arrived.

Corals

disturbances of the magnitude of El Niño. In the Galápagos, though, after most of the corals died, the reef's structures were attacked by organisms that tore apart its framework. Algae covered the coral skeletons, and other organisms, such as the sea urchin *Eucidaris*, came to feed on the algae and remaining coral polyps. In time, much as a beaver fells a tree, the urchins undermined and toppled even massive corals estimated to be over 300 years old and standing up to two meters high.

During and after El Niño, some 95 percent of the reefs in the Galápagos were destroyed. Now erosion is claiming their remains. Studies are going on now to see how the loss of the corals will affect marine life over the years.

Marine Mammals



Galápagos fur seals and sea lions live in the waters and along the islands' shores. They eat fish and squid that live in the normally cool waters of the Galápagos Islands. When the warm waters of the 1982-83 El Niño replaced the normally cool surface waters, these fishes and squids migrated to deeper waters that were cooler. This cool water layer was more than 50 meters below the surface, so beyond the diving depths of most seals and sea lions.

Because their food supply had moved out of reach, the entire population suffered from nutritional stress for several years. In 1982 many pups were born dead because their mothers were undernourished. Even if the pups were born alive they sometimes starved, because mother seals went farther and farther out to sea in search of food, and the pups could not survive without milk until they returned. Many fur seals are still living on their mother's milk at the age of two, so large numbers of the young seals born in 1980 and 1981 died along with the newborns.

By 1983, the female fur seals still hadn't built up enough energy for reproduction, and the birth rate was only 11 percent of that during a normal year. El Niño thus wiped out about four years of the fur seals' population growth. Future generations were affected too, because those large males that bred in early 1982 could not regain

Reptiles

Reptiles in the Galápagos live inland and along the coastal regions. Land iguanas live on the hot, dry volcanic rocks. Their counterparts, the marine iguanas, favor the rocky shoreline and are adapted for swimming and diving. The giant land tortoise also has a marine counterpart, the green sea turtle. The El Niño events of 1982-1983 improved living conditions for the land reptiles, but made life very difficult for the marine species.

Marine iguanas feed on leafy red and green algae attached to shoreline rocks. When El Niño brought the warmer waters, the favored types of algae could no longer survive. They were replaced by brown algae with little nutritional value. The iguanas kept eating, but even though their stomachs were full, they starved. A survey of all the islands in 1985 showed that 45-70 percent of the marine iguanas were gone. Those adults that survived weighed an average of 30 percent less than they had before. Only ten iguanas dug nests on Santa Fe in 1983, down from a normal 1,800 nests. The 1983 hatchlings lived on their yolk sacs until the climate returned to normal, but almost all those hatched in 1982 died. Rough seas and high winds prevented the young iguanas from reaching their food. There was practically no nesting observed in 1984. Green sea turtles experienced a similar decline in their food supply.

Marine Mammals

their energy in time to defend their territories later that year. As a result, almost all of them died and were replaced by smaller males for the next breeding season.

Sea lion colonies were not affected quite as much by the weather change because sea lions can dive deeper to get food. Still, there was less food available nearby, and they had to spend long periods away from new pups. In 1983 the colonies appeared deserted. Most pups born in 1982 had been abandoned.

Sea lions also faced increased susceptibility to disease. The warm water and warmer air weakened them and made it easier for them to catch sea lion pox.

Enough individuals were left of both these species, however, to rebuild their colonies and carry on their lives in the Galápagos. The continuing impact of the El Niño events is still being studied.

Reptiles

Since then, however, cooler waters have returned to the Galápagos and the nutritious green seaweeds once again grow in abundance. Even though the red seaweeds have not returned, the iguana population is recovering well.

Land iguanas and giant tortoises, being land dwellers, were not at the mercy of sea temperatures and waves. In fact, living conditions improved for them over much of the period. Extra rain encouraged plant growth, so the herbivores got more plants to eat and a greater variety of plants.

THE GALÁPAGOS

JASON CURRICULUM

UNIT FOUR

SOCIAL STUDIES

Background
Social Studies

To most Americans and Canadians, the Galápagos are an exotic archipelago known largely through articles in *National Geographic* and citations in travel guides. The islands appear remote and distant, inhabited by grotesque sea and land creatures—a place that would appeal only to marine scientists and a few wealthy tourists in pursuit of the unusual.

Photographs, however, reveal a place of starkly haunting beauty, with almost lunar landscapes. A lava desert covers most of the islands, but its stony surface is interrupted from time to time by clumps of tropical rainforest in the upper elevations, and the cratered cones of volcanoes, some of which are still active.

Because the Galápagos Archipelago was uninhabited in pre-Columbian times, it has limited anthropological significance. Its history is also scant because, even after European exploration in the 16th and 17th centuries, the islands' environment was so inhospitable to humans that the only visitors were those who came in search of food or water. This absence of an enduring history and anthropology is evident in the social studies lessons, all but the last of which have a strong geographic orientation. The concluding lesson, however, *The Galápagos Islands in Time*, connects the islands to world history by putting human experiences of the archipelago in a global context. Through letters, government documents, journal entries, and the like, students learn how the islands have brought frustration and crushed hopes to the whalers, soldiers, pirates, priests, naturalists, and settlers who have arrived there since the Spanish first encountered them in 1535, and how humans in turn have crushed the islands' fragile ecosystem. Even more important, students learn how humans are now working with the Galápagos environment for mutual benefit.

Apart from some recent experiences of cultural adaptation, the importance of the Galápagos to the social sciences is largely in their geography. Most of the lessons in this unit have been structured on the five fundamental themes that presently define geography in the schools. Although each lesson emphasizes a single geographical theme, all the themes are interrelated. Thus no theme is more important than the others, and all are complementary.

As a framework for the study of geography, the five themes also give meaning to the concept of location and establish a context for the connections among peoples, places, and events. The experience of the Galápagos demonstrates how the themes can be applied to a specific area on Earth's surface. Rather than making statements about the nature of geography, the five themes help students answer questions. Here are the themes and the questions they pose:

1. *Location*: Where are things located?

2. *Place*: What makes a place so special that it can be distinguished from all other places?

3. *Human-Environmental Interaction*: What are the relationships among people and places? How do people adapt to their environment? How do they change it to better suit their needs?

4. *Movement*: What are the patterns of transfer of people, products, services, and information?

5. *Regions*: How can the Earth be divided into manageable units for study, so that the physical and cultural features of a complex planet can be made understandable?

Within a few years after the 1984 publication of the five themes by the Association of American Geographers and the National Council for Geographic Education in the *Guidelines for Geographic Education: Elementary and Secondary Schools*, the United States Congress passed the first joint resolution establishing an annual Geography Awareness Week. Congress has designated such a week each year since 1987. This year Geography Awareness Week begins December 1, coinciding with the JASON Project's investigations in the Galápagos and the visits by thousands of students to downlink sites across the country. Each of these two complementary events invites us to develop new insights about the world and to understand how tenuous it is as a sustainable habitat. The Galápagos Archipelago provides a valuable case study for the adult citizens of the future. During Geography Awareness Week, some of them will embark with JASON upon a mission that draws on the physical and social sciences to increase their knowledge of an ever more interconnected and interdependent world.

WHERE IN THE WORLD?

(Absolute and Relative Location)

4.1

Rationale

Every place in the world has both an absolute and a relative location. The absolute location of the White House, for example, can be stated as 1600 Pennsylvania Avenue, NW, Washington, DC, USA. The relative location of the United States can be stated as northwest and south of Canada and north of Mexico or between the Atlantic and Pacific Oceans. Each statement provides information about where a place is. *Latitude* and *longitude* will help us find the absolute location of the Galápagos Archipelago, the site of the JASON Project exploration. *Relative location* will help us understand the location of the islands in relation to other places.

Objectives

Students will:

Read maps to determine the absolute and relative locations of selected places.

Locate the islands of the Galápagos Archipelago by latitude and longitude coordinates.

Identify the islands of the Galápagos Archipelago by name.

Materials

- Classroom wall map of the world or transparency made from Master 1.2a, World Map
- Classroom wall map of the United States or transparency made from Master 4.1a, The United States and Southern Canada
- Overhead projector (*optional*)
- Student copies of Master 1.2a, World Map (Students should already have these in their JASON journals.)
- Student copies of Master 1.2b, Galápagos Map (also in journals)
- Atlases, almanacs, and other general reference books for class use
- Student copies of Master 4.1b, Where in the World Worksheet
- Compass for finding coordinates (*optional*)
- Back of Master 4.1b, Answer Key
- Student copies of Master 4.1c, Place Name Table

VOCABULARY

Ab•so•lute lo•ca•tion - a point on a map or globe expressed as the intersection of lines of latitude and longitude.

An•a•lem•ma - a graduated scale, shaped like the figure eight, usually found on sundials and globes.

Ar•chi•pel•a•go - a group of islands sharing common physical and locational characteristics.

Co•or•di•nates - the intersection of latitude and longitude lines that express (in degrees north or south and east or west) the location of a point on a map or globe.

Lat•i•tude - the angular distance (in degrees) around the globe north and south of the equator.

Lon•gi•tude - the angular distance (in degrees) around the globe east and west of the prime meridian.

Min•ute - one sixtieth of the distance between two lines of latitude or longitude.

Quad•rants - the quarters that result when the world is divided by the equator and the prime meridian.

Rel•a•tive lo•ca•tion - location expressed in terms of a reference point or area.

Scale - the ratio between map distance and real Earth distance; for example, 1 centimeter represents 1 kilometer. Scale will vary from map to map.

Procedure

A. Introduction

Use a wall map of the world or Master 1.2a to orient students to the relative locations of the United States, Central America, and South America. Identify the specific location of the United States, the Panama Canal, Ecuador, and the Galápagos Archipelago (*Archipielago de Colon*). Use the scale on the map to measure the distance between the west coast of Ecuador and the Galápagos (approximately 1000 kilometers, or 600 miles).

B. Lesson Development

1. Explain: Relative location tells where a place is in relation to other places. Every place has a relative location. Relative location helps us develop an accurate idea of the Earth's surface. We can use relative location to describe the United States and Ecuador. Ask: What countries does each border? Where is each in relation to large bodies of water? On what continent is each country located? In what direction would you sail from Ecuador to the Galápagos and from the Panama Canal to the Galápagos?

2. Using the wall map of the United States or Master 4.1a, ask students to describe their city's location in relative terms, then describe their location in relation to the center where they will go to participate in the JASON Project Galápagos expedition. Next ask students to describe their location in relation to the Galápagos, and finally, that of the Galápagos in relation to Ecuador.

3. Distribute the world map and ask the students to locate and label the following:

Ecuador
Colombia
Tropic of Capricorn
Panama Canal
Peru
United States
Mexico
Atlantic Ocean
Canada
Venezuela
Galápagos Islands
Caribbean Sea
Pacific Ocean
Brazil
Tropic of Cancer

4. To conclude this section of the lesson, ask students to describe the relative locations of selected places you identify on the map. Remind them that the equator, the Tropic of Cancer, and the Tropic of Capricorn are imaginary lines drawn for navigational and meteorological purposes. Geographers call them *sun lines*. Each of the two Tropic lines is 23.5° north and south of the equator and delineates one of the extremes of location where the sun's rays shine directly overhead at noon on the Earth's surface, between June 20 and 22 (at the Tropic of Cancer) and between December 20 and 22 (at the Tropic of Capricorn).

TEACHER TAKE NOTE

If your students understand the nature and function of the analemma on the globe, this part of the lesson will be an excellent opportunity for review.

5. Indicate a point on the world map somewhere in the Pacific Ocean. Ask students how they would describe this location in relative terms. It will be difficult to describe because of the vastness of the Pacific Ocean. Explain that some locations are very difficult to describe in relative terms

because they do not seem to have clear connections to other places in the world. Absolute location (the use of intersecting latitude and longitude lines) can orient people in these situations, and pinpoint any place on Earth more precisely than relative location. Review with the class what they already know about latitude and longitude. Practice spot location, using the wall map of the world and the student desk maps. The largest of the Galápagos Islands, for example, lies on the equator (0° latitude) between 89° and 92° west longitude. All of the islands lie within a little more than 2° of the equator.

5. Distribute Master 4.1b, Where in the World Worksheet. Have students use classroom atlases, almanacs, reference books, and wall maps to complete the worksheet. Review the worksheet answers with the class.

TEACHER TAKE NOTE

The museums and other downlink sites listed by latitude and longitude on Master 4.1b were participants in the project as this curriculum went to press. Other sites may have been added since that time.

6. Distribute copies of Master 4.1c, Place Name Table, and (if students don't have them in their JASON journals), copies of Master 1.2c, the Galápagos map. Explain that many places in the world that were explored by Europeans in the 16th through the 19th centuries have two or more names. An early explorer might give a place one name, then it would receive another as a result of either purchase or conquest. When the British acquired New Amsterdam from the Dutch, for example, they called it New York. Darwin used English place names in his scientific writing because in 1835, when he visited the area, it was claimed by the British. Now, however, all scientific writing uses the Spanish names because the islands belong to Ecuador, where the official language is Spanish. Have the students use the place name table to locate the 18 main islands and identify each by its English and Spanish names.

TEACHER TAKE NOTE

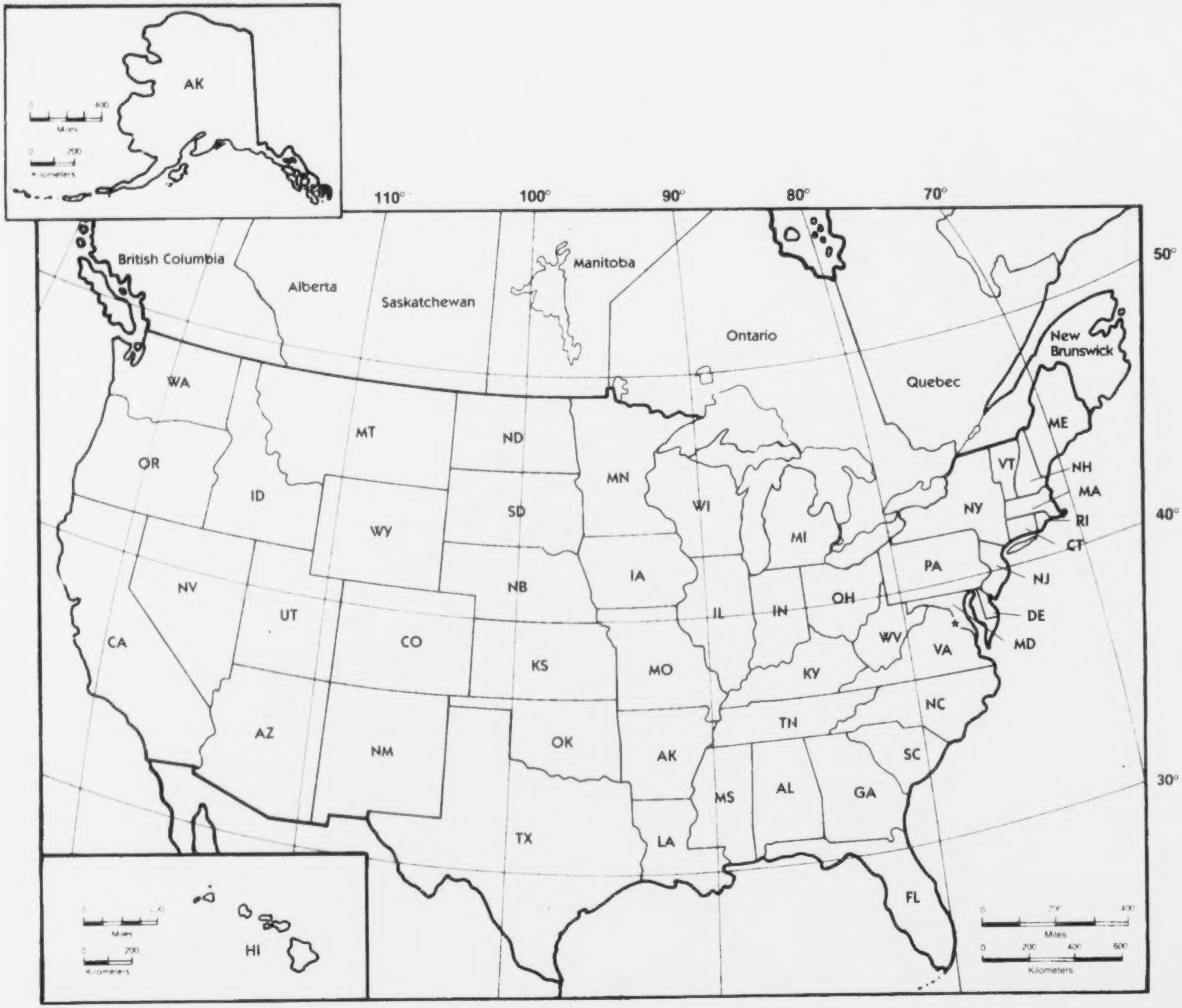
Some of the islands have more than one Spanish name. Floreana, one of the smaller islands, is also known as Santa Maria, and Santiago is sometimes called San Salvador.

C. Conclusion

Review Master 1.2c, the Galápagos map, with your students. Ask them to identify the absolute locations for selected islands and then describe their relative locations. Since the JASON exploration will be centered between Fernandina and Isabela, be sure to emphasize their locations in the review.

The United States and Southern Canada

MASTER 4.1 a


AK
0 400
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British Columbia
Alberta
Saskatchewan
Manitoba
Ontario
Quebec
New Brunswick
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MASTER
4.1 b

Where in the World Worksheet

1. The coordinates below each relate to a downlink center for the JASON project. What is the name of the city at each of these coordinates?*

(a) 40° 40′N 75° 25′W ________________________________

(b) 42° 20′N 71° 07′W ________________________________

(c) 35° 15′N 80° 50′W ________________________________

(d) 41° 49′N 87° 37′W ________________________________

(e) 32° 44′N 96° 48′W ________________________________

(f) 39° 45′N 104° 59′W ________________________________

(g) 43° 45′N 79° 20′W ________________________________

(h) 27° 25′N 80° 20′W ________________________________

(i) 30° 20′N 81° 40′W ________________________________

(j) 35° 07′N 90° 03′W ________________________________

(k) 43° 03′N 87° 55′W ________________________________

(l) 44° 58′N 93° 15′W ________________________________

(m) 27° 27′N 82° 30′W ________________________________

(n) 38° 50′N 77° 00′W ________________________________

(o) 48° 26′N 123° 23′W ________________________________

(p) 41° 30′N 70° 40′W ________________________________

2. Select one of the cities above and supply the following information:

(a) Name of the city ________________________________

(b) Location by degrees of latitude and longitude ________________________________

(c) Something for which the city is known (e.g., Boston, baked beans)

____

(d) At least one other large city at the same approximate latitude as the city you chose

____

3. Write the coordinates of your home town. ________________________________

4. All of the downlink centers are located on the continent of ________________________________

5. In what Canadian province is Victoria located? ________________________________

6. Woods Hole Oceanographic Institution is a major sponsor of the JASON Project. Find Woods Hole on a classroom map and describe its relative location.

____

____

7. Through which island in the Galápagos does the equator pass?

____

*As noted in *Goode's World Atlas*, 18th Edition. Chicago: Rand McNally, 1990.

Back of Master 4.1b

Answer Key

1. a. Bethlehem, PA—Lehigh University
    b. Boston, MA—Boston Museum of Science
    c. Charlotte, NC—Science Place
    d. Chicago, IL—Museum of Science and Industry
    e. Dallas, TX—The Science Place
    f. Denver, CO—Denver Museum of Natural History
    g. Don Mills (near Toronto), Ontario—Ontario Science Center
    h. Fort Pierce, FL—Harbor Branch Oceanographic Institute
    i. Jacksonville, FL—DuVal Public Schools
    j. Memphis, TN—Memphis Pink Palace Museum
    k. Milwaukee, WI—Center for Great Lakes Studies
    l. Minneapolis, MN—Bell Museum of Natural History
    m. Sarasota, FL—Mote Marine Laboratory
    n. Washington, DC—National Geographic Society
    o. Victoria, British Columbia—Royal British Columbia Museum
    p. Woods Hole, MA—Woods Hole Oceanographic Institution
2. Answers will vary.
3. Answers will vary.
4. North America
5. British Columbia
6. Woods Hole is located on the peninsula in southeastern Massachusetts known as Cape Cod. It is between Buzzards Bay on the west and Nantucket Sound on the east, about 136 km (85 miles) southeast of Boston. Falmouth is the nearest town.
7. Isabela

Place Name Table

Island	Official Place Name	British Place Name
1.	Darwin	Culpepper
2.	Wolf	Wenman
3.	Fernandina	Narborough
4.	Isabela	Albemarle
5.	Pinta	Abingdon
6.	Marchena	Bindloe
7.	Genovesa	Tower
8.	Santiago (San Salvador)	James
9.	Rábida	Jervis
10.	Pinzón	Duncan
11.	Seymour	N. Seymour
12.	Baltra	Baltra
13.	Santa Cruz	Indefatigable
14.	Plaza	Plaza Islets
15.	Santa Fé	Barrington
16.	Santa Maria (Floreana)	Charles
17.	San Cristóbal	Chatham
18.	Española	Hood

PREPARING FOR AN EXPEDITION TO AN UNINHABITED ISLAND

(Place)

4.2

Rationale

The JASON Project will explore several sites in the Galápagos Islands. Dr. Tom Simkin, a scientist who has done extensive research in the Galápagos, frequently works on Santiago (also known as San Salvador), one of the uninhabited islands. This lesson is based on Tom's description of a research mission to this volcanic island.

Objectives

Students will:

Locate Santiago (San Salvador) Island on a map.

Plan a short stay on the volcanic island.

Materials

- Classroom wall map of the world or transparency made from Master 1.2a, World Map
- Overhead projector (*optional*)
- Master 4.2a, Map of the Galápagos with James Bay Indicated
- Master 4.2b, An Expedition on Santiago
- Master 4.2c, Santiago Expedition Worksheet

Procedure

A. Introduction

Invite students to pretend that they are planning an expedition to the island of Santiago. Explain that in preparing to travel to a remote area they must consider four problems: subsistence, transportation, work, and comfort. Their backpacks must accommodate clothing, food, water, and tools, and will weigh between 18 and 33 kilos (approximately 40 to 70 pounds). What they take will be determined by how much weight they can carry on their backs. Optional items such as tents, sleeping bags, cameras, and extra tools would be convenient, but students have to consider the extra weight.

Ask students what they think the weather will be like in Santiago. Locate the Galápagos Archipelago on a world map or project Master 1.2a, World Map. Explain that Santiago and the other Galápagos Islands are unlike most equatorial regions because they lie in a dry zone of the Pacific. The island of Santiago is very dry near the shore but becomes hotter and more humid near the plateau. There are many

VOCABULARY

Al•tim•e•ter - a type of barometer used to measure altitudes and to find distance above sea level.

Ar•chi•pel•a•go - a group of islands sharing common physical and locational characteristics.

Ba•salt - the dark, dense rock that is produced by a lava flow.

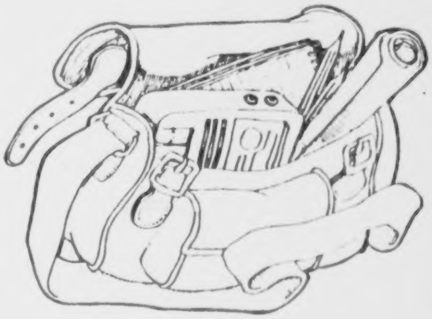
Cin•der la•va - sharp, rough, or loose lava.

Ep•i•phytes - plants that grow upon other plants but do not receive food, water, or minerals from them; rather, the plants receive nourishment from the atmosphere.

Ga•rú•a - light rain or drizzle (Spanish).

Hip chain - an instrument used to measure distance.

Rope la•va - smooth lava of the type geologists describe as "ironed."



clouds at the top of the mountain and fog often settles in. When there is cloud cover, with *garúa* or light drizzle, the temperature is around 22°C and very humid. On sunny days, the temperature is around 26°C and very humid. Tom and the other scientists who work there use special pens to record their data. The pens use India ink, an oily ink that does not fade in the humid air.

B. Lesson Development

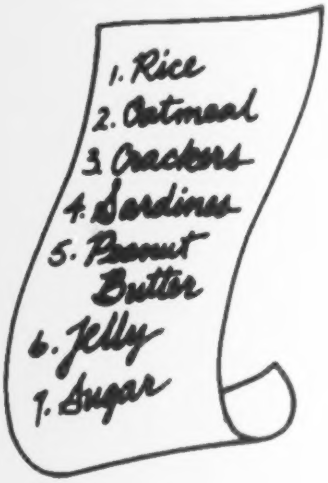
1. Arouse students' interest in planning their trip by asking them to make a list of the food, tools, and other equipment that they think they should take along. Ask:

- How will you pack your food, supplies, and clothing for an expedition to an uninhabited island?

- How much weight do you think you can carry?

- What kinds of food will you need? (Have students estimate the weight of the food and water that each will need for a seven-day trip and make a shopping list.) How will you package your food and water?

- What tools and equipment will you need for camping and conducting research?



2. Read Tom's list of food items for the trip, and have students compare their lists with his: rice, oatmeal, sweet and salt crackers, cans of sardines, peanut butter, jelly, sugar, dried fruit punch mix with sugar, coffee, onions, lemons, oil, hot sauces, dried packaged soups, and three liters (about three quarts) of water per day per person. (Three liters of water weigh almost three kg, over six pounds.)

Tom measures his rice, oatmeal, crackers, dried fruit punch mix, and coffee into one-meal quantities and puts them into plastic bags.

3. Have students compare their lists of equipment with Tom's list. Tom's list includes: measuring tape, altimeter, thermometer, notebook, pen, hip chain (an instrument for measuring distances), stove, and one change of clothing in a plastic bag.

4. Ask the students if they are planning to take any of the optional items mentioned in the introduction to this lesson. Why or why not?

TEACHER TAKE NOTE

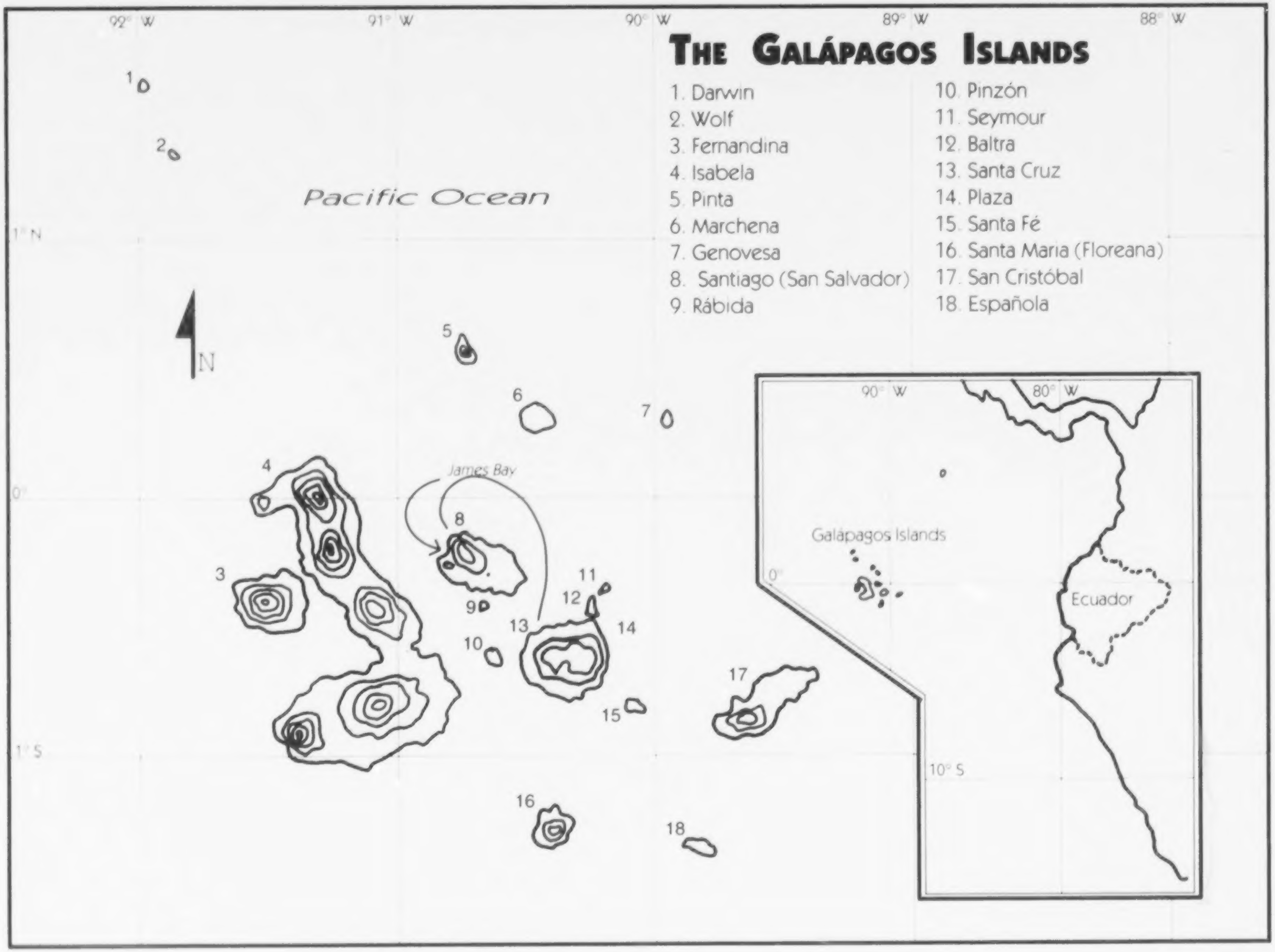
Students will find out why Tom packs his clothing in a plastic bag when they do the worksheet activity.

5. Give each student copies of the Galápagos map; Master 4.2b, An Expedition on Santiago; and Master 4.2c, Santiago Expedition Worksheet. Read and discuss the information with the students, then have them complete the worksheet.

C. Conclusion

Assign students to write an article for their local newspaper about their trip to Santiago. The article should include: the location and climate of the Galápagos islands; Santiago's land formations and vegetation; routes traveled to Santiago and on the islands; reasons for going to the islands; length of time the trip took; and ways this trip differed from other trips they have taken.

The Galápagos Islands


92° W
91° W
90° W
89° W
88° W
1° N
0°
1° S
Pacific Ocean
N
James Bay
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
90° W
80° W
Galápagos Islands
0°
Ecuador
10° S

THE GALÁPAGOS ISLANDS

1. Darwin
2. Wolf
3. Fernandina
4. Isabela
5. Pinta
6. Marchena
7. Genovesa
8. Santiago (San Salvador)
9. Rábida
10. Pinzón
11. Seymour
12. Baltra
13. Santa Cruz
14. Plaza
15. Santa Fé
16. Santa Maria (Floreana)
17. San Cristóbal
18. Española

MASTER 4.2 b

An Expedition on Santiago

Directions: *Read the information and use it to answer the questions on the worksheet, Master 4.2c.*

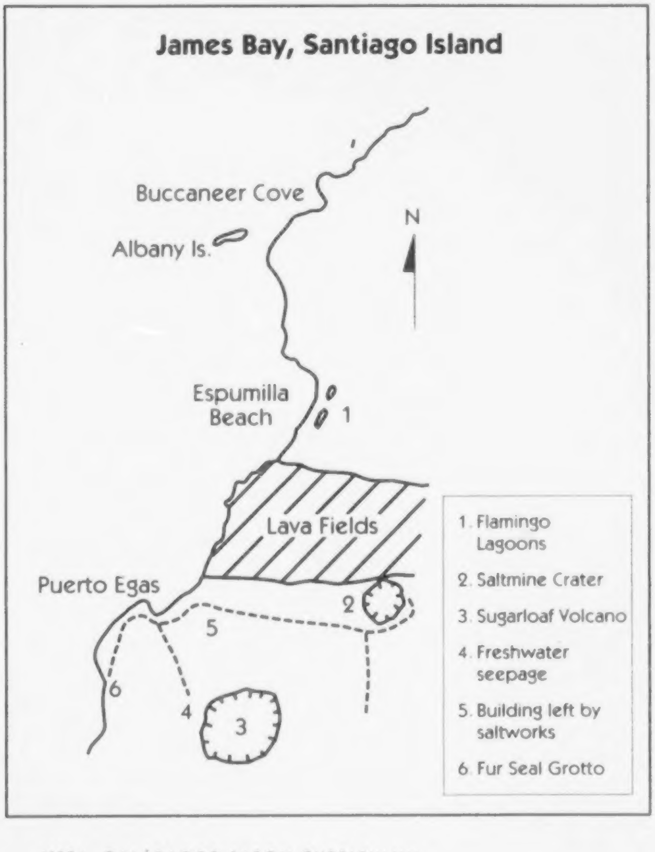
Imagine our class is part of an expedition that will fly to Ecuador and then continue on to Santa Cruz, an island about 1000 km (600 miles) from the South American continent. The island is volcanic, a basaltic volcano that has risen out of the ocean.

At the Darwin Station on the island of Santa Cruz we will purchase enough supplies to last seven days. After purchasing supplies, our expedition will travel by boat to the shore of Santiago. This will take half a day. The area along James Bay, where we put ashore, has very little vegetation—only a few cacti and trees that can grow in very dry regions.

After arriving on shore and setting up a campsite, we will unpack the change of clothes that we brought in a plastic bag and tie it to a tree. These bags, hanging high and dry, will be a welcome sight when we return from the expedition.

We will begin the expedition by walking up the slopes of the volcano. The slopes may be covered with layers of dust or strips of lava. There are two kinds of lava found on the island: rope lava and cinder lava. Rope lava is called *pahoehoe* (pah•hoy•hoy) in Hawaiian and *planchanda* (plahn•chahn•dah) in Spanish. It is "ironed," or smooth, and relatively easy to walk on. Cinder lava is called *aa* (ah•ah) in Hawaiian and *quemado* (kay•mah•doh) in Spanish. It is composed of cinders that are sharp, rough, and loose, and it is difficult to walk on. We cannot always choose the easiest route, however, because of the direction the expedition must travel.

After we've been walking for about an hour, we'll notice that the slopes become steeper and the vegetation thicker. There are no roads or trails. The journey continues for about another five hours. It is getting hotter and more humid as we ascend the slope, and everyone's walking more slowly. Finally, reaching the plateau, we take a rest.

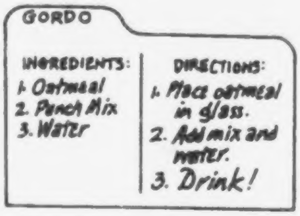


James Bay, Santiago Island

The other side of the plateau has lava tube caves where water has condensed. We will put pans under the drips to collect extra water for drinking and cooking.

We will set up a second camp near the caves. For the next four or five days we will travel to other parts of the volcano to find tortoises and study them. While looking for tortoises, we may also see hawks, birds, wild pigs, goats, and many insects, including ticks and big, biting flies. There will be fields of ferns growing in volcanic cones and craters, and *epiphytes*, plants that grow on other plants.

When supplies become low we will start the walk down the volcano. Back on James Bay, we'll bathe in the ocean and put on our clean clothes for the boat ride back to Santa Cruz. We'll relax after our long journey with gordo, a treat Tom enjoys each evening on Santiago.



GORDO

INGREDIENTS:	DIRECTIONS:
1. Oatmeal	1. Place oatmeal in glass.
2. Punch Mix	2. Add mix and water.
3. Water	3. Drink!

261

MASTER
4.2 c

Santiago Expedition Worksheet

Answer the questions below:

1. How was the island of Santa Cruz formed?

2. Name the two types of lava found on Santiago (San Salvador). Compare and contrast them.

3. Why didn't the expedition drive to the plateau?

4. Why were the lava tube caves useful to the expedition?

5. What time do you think the group returned to the campsite each day, and why?

6. Draw a map of the islands and trace the route from Santa Cruz to Santiago. Refer to your Galápagos map.

Back of Master 4.2c

Answer Key

1. The island was formed by volcanic activity that began on the floor of the ocean. (The text says it rose out of the sea.)

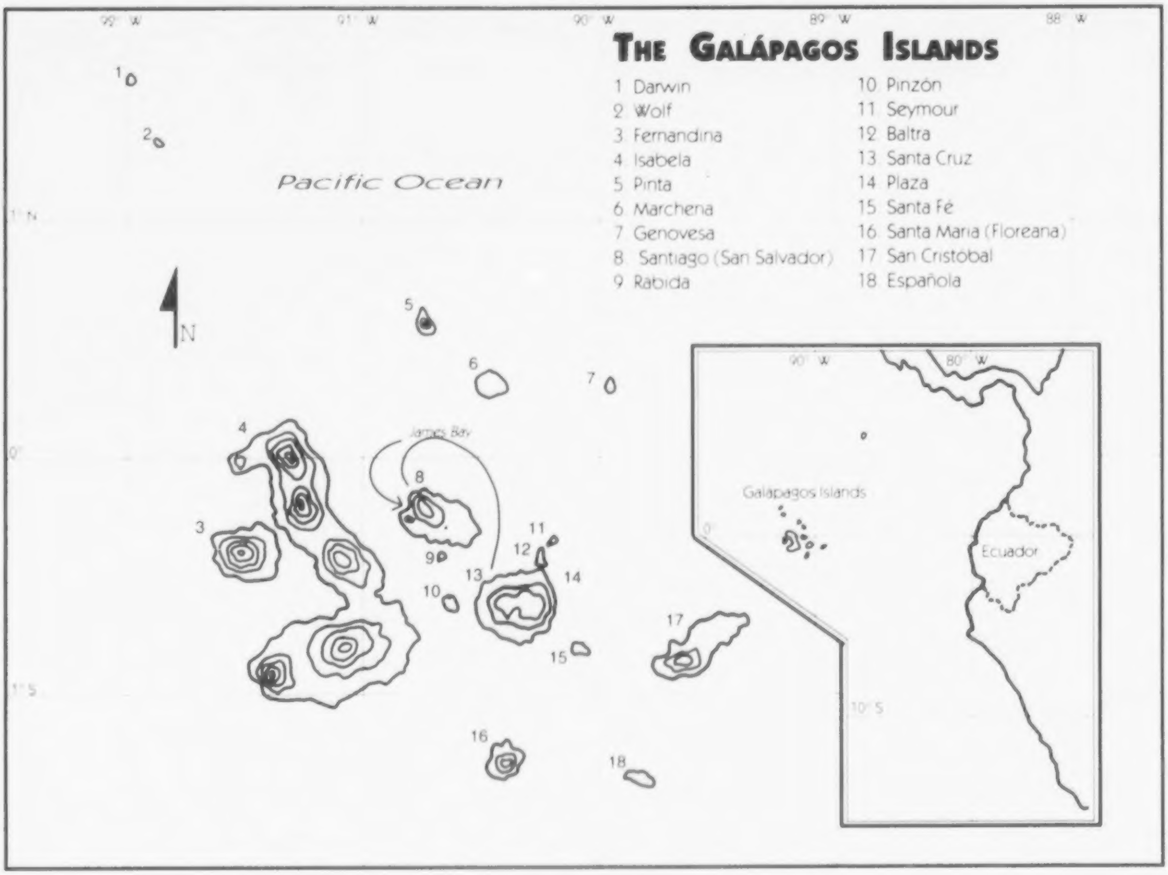
2. There are two kinds of lava found on the island: rope lava and cinder lava. Rope lava is called *pahoehoe* (pah•hoy•hoy) in Hawaiian and *planchanda* (plahn•chahn•dah) in Spanish. It is "ironed," or smooth, and relatively easy to walk on. Cinder lava is called *aa* (ah•ah) in Hawaiian and *quemado* (kay•mah•doh) in Spanish. It is composed of cinders that are sharp, rough, and loose, and it is difficult to walk on.

3. The island is uninhabited, and there are no roads or trails.

4. Although each expedition member carries a supply of water, the lava tube caves are a source of extra water.

5. The group must return to the campsite at dark because there is no electricity on the island.

6. Accept all reasonably accurate drawings. One route from Santa Cruz to Santiago is marked on the map below.


92° W
91° W
90° W
89° W
88° W
THE GALÁPAGOS ISLANDS
1 Darwin
2 Wolf
3 Fernandina
4 Isabela
5 Pinta
6 Marchena
7 Genovesa
8 Santiago (San Salvador)
9 Rabida
10 Pinzón
11 Seymour
12 Baltra
13 Santa Cruz
14 Plaza
15 Santa Fé
16 Santa Maria (Floreana)
17 San Cristóbal
18 Española
Pacific Ocean
1° N
0°
1° S
N
James Bay
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
90° W
80° W
Galápagos Islands
0°
Ecuador
10° S

DECISION MAKING FOR THE GALÁPAGOS

4.3

ACTIVITY ONE

You're in Charge

(Historical Choices)

Rationale

Ecuador's 19th-century decision to use the Galápagos as a penal colony affected the development of settlements in the archipelago. Students can gain insight into that decision by placing themselves in a position of authority and practicing decision making.

VOCABULARY

Al•ter•na•tive - a choice; something that can be chosen instead of something else.

Pri•or•i•ty - a first choice; something that is chosen, done, or used before all other alternatives.

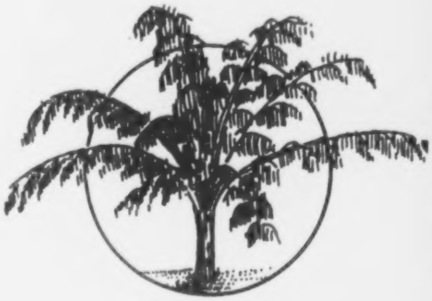
Objectives

Students will:

Analyze the Galápagos Islands from geographic, economic, and social perspectives as a potential site for colonization.

Develop a priority list of goals in order to make a political decision on the future of the Galápagos Islands.

Decide what to do with the islands and discuss the consequences of this decision.



Materials

- Student copies of Master 4.3a, Factors Influencing the Decision
- Classroom wall map or transparency made from Master 1.2a, World Map
- Overhead projector (*optional*, only if using map transparency)

Procedure

Teacher Preparation

If at all possible, read the relevant chapters of John Hickman's *The Enchanted Islands* (See Unit 4 bibliography) as preparation for teaching this lesson.

A. Introduction

Tell students that between 1822 and 1830, Simón Bolívar established a union of Ecuador, Columbia, and Venezuela. In 1830 Ecuador withdrew from this union and established an independent government. The new government was shaky in its first years. Any political decision could threaten its stability.

Present this hypothetical situation to your students: You are the ruler of Ecuador in 1832. Your country has just established control over the Galápagos Islands. For years no one has shown any interest in these barren and seemingly useless islands, but now other nations are approaching you about them. Some are even willing to pay a substantial amount to claim the archipelago.

TEACHER TAKE NOTE

This activity will probably be most successful with older students, although some elementary classes may enjoy it.

B. Lesson Development

1. Explain to students, each of whom is to think of him/herself as the ruler, the positions of some other Ecuadorian leaders. Your foreign policy advisor and trusted friend wants you to keep the islands and establish a thriving colony with a trading system similar to that used by the British.

Your chief of police, who helped you rise to power, believes that the islands would be ideal for a penal colony. Taking his advice would help you rid your society of troublemakers and solidify your political power.

2. Present the alternatives. You (students/rulers) may choose to:

- Sell the islands and reap the substantial financial rewards.

- Colonize the islands, encourage people to settle them, and establish an economic center that could provide dividends in the future.

- Establish a penal colony to solve some of your country's social problems and remove any threats to your political power.

- Keep the islands and do nothing with them.

- Develop and implement another alternative.

3. Have students brainstorm some of the things they should do before making a decision. As a class, or in small groups, construct a checklist of steps in the process. Guide the discussion so that the list eventually includes the following items:

- Identify the problem or issue.

- Establish goals and set priorities based on your value system.

- Obtain the information you need to make a sound decision.

- List the positive and negative consequences of each possible alternative.

- Choose among the alternatives and support your choice.

4. After the students complete their lists, distribute Master 4.3a, Factors Influencing the Decision, and allow time for reading, or read the material together as a class. Provide a world map or project the transparency so students can locate places mentioned in the reading.

5. Challenge students to select one of the alternatives listed in step 2 above, either as individuals or in small groups. Initiate a class discussion on the role of values in decision

making. Explain that people's values, the things that are important to them, are critical components in the decision-making process. In this case, for example, each student/ruler must decide between keeping his or her job (maintaining political power) and strengthening the country politically and economically. Sometimes these goals have similar consequences; a ruler can use power to help the people. Sometimes they conflict, as when a ruler's notion of security puts the people at the mercy of a tyrannical military force.

C. Conclusion

Take a poll of the results to see which decision was most popular. Discuss the advantages and disadvantages of each decision.

Adaptations

For younger students

Students who are familiar with concept webbing may use it to help organize the decision process.

For older students

If time allows, challenge students to learn more about the background of this historical decision and its actual outcome. Recommend Hickman and other resources from the unit bibliography.

ACTIVITY TWO

Should the Galápagos Go to the Dogs?

(Contemporary Choices)

Rationale

When introduced species enter a fragile ecosystem like the Galápagos Archipelago, they are likely to be destructive to native plants and animals. Feral (wild) dogs have become especially dangerous predators on some of the islands in recent years. Controlling their population is a serious challenge.

Objectives

Students will:

Develop a hypothesis about the feral dog population from anecdotal information.

Analyze statistical data about the environmental effects of the feral dog population.

Materials

- Student copies of Master 3.7d, Introduced Species and their Distribution in the Galápagos Islands, from the science unit

VOCABULARY

Cam•ou•flage - a natural or artificial coloration that makes something difficult to see.

E•rad•i•ca•tion - doing away with, or removal.

Fe•ral - wild; in this case, having escaped from domestication and become wild.

Hab•i•tat - the natural environment that supports life.

- Student copies of Master 4.3b, How the Galápagos Almost Went to the Dogs
- Overhead projector

Procedure

A. Introduction

Explain that humans have introduced many different animal species into the Galápagos Islands. Many of the animals introduced as domestic animals have later became feral (wild). One of the most destructive is the wild dog. The purpose of this lesson is to evaluate some information about the dogs and the effects of their presence

TEACHER TAKE NOTE

Be prepared for strong emotional reactions to the idea of eradicating dogs. It may help to emphasize that feral dogs are not affectionate pets like those the students know and love. These feral dogs have adapted to a harsh environment by learning to eat baby animals of other species. Dog packs have also attacked scientists and game wardens.

B. Lesson Development

1. Distribute copies of Master 3.7d, Introduced Mammals in the Galápagos. Briefly discuss where the dogs were introduced and note where other mammals have been introduced into these islands.

2. Distribute Master 4.3b, How the Galápagos Almost Went to the Dogs. Give the class time to read the essay and then hold a brief discussion on its factual content. Ask:

- How did the dogs get to the islands?
- How did they become feral?
- Which islands do the dogs presently occupy?
- Where do they live on the islands?
- What is their prey?
- What efforts are underway to control the dogs?
- How serious is the threat they pose?

3. Now ask the students, in a general class discussion, to use the information in the essay to develop a hypothesis about the feral dogs' effects on the environment they inhabit. When the class has reached consensus, write the hypothesis on the chalkboard. Possible hypotheses might include:

- The introduction of dogs has had a drastic effect on the native species.
- Not enough scientific evidence is available to measure the full effects of the wild dogs on the environment.
- If left unchecked, feral dogs could eventually exterminate some of the reptile and bird species on Santa Cruz and Isabela islands.

4. Copy the table below on the chalkboard, and ask the students to evaluate their hypotheses, using the data from the table as well as the information from the essay. What conclusion can the class reach? Would more information than they have be helpful? If so, what kind? How accurate is the hypothesis? Does it need to be rewritten to reflect the data?

C. Conclusion

Ask students why the feral dog problem in the Galápagos is an example of human/environmental interaction. They may explain that the introduction of the dogs by humans has had serious consequences for the natural environment, including the native species. The ecological balance has been disturbed to the point that some species almost became extinct.

Ask students to summarize any general conclusions they can draw from this case study about human beings interacting with their environment.

Feral Dog Characteristics

Island	Maximum Population	Location	Average Pack Size	Species Endangered by Dogs
Santa Cruz	70+	Coastal	2.6	Marine iguanas, fur seals, bluefooted boobies, iguana eggs
Isabela	500+	Coastal Highland	2.6 7.7	Same as Santa Cruz
San Cristobal	0*	Coastal	0	None because of control
Santa Maria (Floreana)	0*	Coastal	0	None because of control

** Dogs were eradicated in the early 1970s.*

Factors Influencing the Decision

It is 1832, and Ecuador, the nation you rule, has just recently established its independence from Spain. Ecuador is an extremely poor republic with many political, social, and economic problems. The ruler before you was overthrown in a bloody revolution. You and the others in power are preoccupied with trying to survive and preserving a minimum of law and order. At the same time, you would like to see your country prosper.

Lately, various other countries have expressed interest in your Galápagos Islands, even though the islands seem to have no valuable resources in large enough amounts to export; they are outside the normal shipping routes; and they can't support large numbers of people. England wants to own the Galápagos as settlement for a loan to Ecuador because it has little hope of the loan being repaid in cash. The United States is interested because it believes that the Galápagos contain large deposits of guano (bird droppings, a natural fertilizer). France, governed by the Emperor Napoleon III, wants to gain control over Mexico and all the rest of Latin America. Chile and Peru would like to increase their territories in the Pacific and are fiercely jealous of each other. The U.S., Spain, England, France, Chile, and Peru all resist any other nation's attempts to gain advantages in the Pacific.

Because the Galápagos have attracted so much attention, control over them is becoming an issue of Ecuador's national honor. Giving away or selling the nation's right to them could result in political defeat for you and your friends.

Some Ecuadorians believe that, with time and considerable investment, the Galápagos could develop into a highly profitable business operation. The islands have small amounts of land suitable for growing cash crops, such as corn, potatoes, and sugar. Local farmers could make money selling fruits, vegetables, and other fresh food to whalers. More importantly, orchilla (dyer's moss) is available. Dyes could be manufactured and sold at a profit. The majority of the islands, however, are barren and filled with active volcanoes.

The prisons in your country are overflowing with soldiers who have tried to mutiny, political prisoners, and lawbreakers. Social disorder is on the rise. To lessen your social and political problems, you have considered holding mass executions and borrowing money to build more prisons. Both alternatives have serious drawbacks.

MASTER
4.3 b

How the Galápagos Almost Went to the Dogs

Early settlers of the Galápagos brought dogs to the islands as pets and work animals. Whalers and sailors may have brought dogs to hunt game. Some of these dogs were abandoned or strayed away from their owners. At present wild dogs live on two of the five inhabited islands, Santa Cruz and Isabela. We find these dogs roaming in packs on Isabela and Santa Cruz, where they are a genuine menace. The dogs have adapted to the harsh environment of the bare lava fields by learning to feed on several species of native animals. Members of scientific expeditions have reported being attacked by packs of dogs.

In the 1970s, local farmers and wardens of the National Park Service eliminated the packs on San Cristóbal and Floreana in a carefully controlled eradication program. Because the program was successful, it is not likely that the feral dogs will return to these islands, now carefully patrolled by National Park wardens and guides. Unfortunately, the program was also time-consuming and a strain on the Park Service's limited budget.

The wild dogs on Santa Cruz look very much like the domestic dogs on that island. They are mostly white with scattered patches of brown or black. The wild dogs live in the island's coastal area, where they spend their days, away from the scorching rays of the equatorial sun, in cool lava holes or shallow basins they have dug in the soil. At night they stalk their prey, which includes marine iguanas (lizards), blue-footed boobies (sea birds), fur seals, and penguins. The dogs have been particularly destructive to the iguanas. Biologists estimate that they have killed more than 15 percent of the marine iguana population. In some of the coastal sections of Santa Cruz, the dog packs have completely eliminated the marine iguanas.

The situation is about the same on nearby Isabela. The dogs hunt along the coastlines there as well. They range the shoreline alone or in small packs, because the coastal birds and reptiles have never learned to fear humans or other animals. Dogs also live in the highlands of the southern volcanoes where they attack wild cattle. These dogs are mostly dark in color, so they're easily camouflaged against the black, brown, and green of the landscape. Many dogs are needed to make a kill when wild cattle are the prey, so packs are larger than those on the lava fields by the sea.

Because there is growing concern that the dogs will cross the Perry Isthmus from southern Isabela to the northern part of the island, the Ecuadorian government has begun an eradication program on this island. The program is designed to protect the island's large population of tortoises, land iguanas, flightless cormorants, penguins, and fur seals from becoming victims of the feral dogs. The plan is too new to measure its success.

The situation in the Galápagos is serious indeed, but it is not hopeless. Scientists must make additional long-term studies to evaluate the dogs' effects on the environment. Until all the evidence is in, responsible and humane eradication programs will help preserve one of Earth's unique environments.

MAPPING DARWIN'S ROUTE

(Location, Movement)

4.4

Rationale

Darwin's visit to the Galápagos Islands was only one of many stops on a round-the-world voyage. This activity will help students to view the islands in the context of the entire trip.

Objectives

Students will:

Note that map coordinates are conventionally expressed in degrees and minutes, with latitude preceding longitude.

Plot highlights of Darwin's voyage on a blank world map, using coordinates of latitude and longitude.

Use maps to see the Galápagos in their world setting.

Associate specific places with Darwin's significant findings and observations.

Materials

- Master 4.4a, From Charles Darwin's Journals, Teacher Background Reading (*optional* for students)
- Master 4.4b, Charles Darwin's Journey: A Mapping Worksheet
- Back of Master 4.4b, Answer Key
- Student copies of Master 1.2a, World Map (from Unit 1)
- Transparency made from Master 4.4c, World Map with Coordinates (*optional*)
- Overhead projector (*optional*)
- Master 4.4c, Answer Key to Darwin's Journey
- Glue sticks or tape for assembling maps
- World atlases and maps for reference
- Pencils
- Pens or pencils of a second color
- Compasses for finding coordinates (*optional*)

Procedure

Teacher Preparation

Read Master 4.4a, From Charles Darwin's Journals. You can use this material for enrichment when students have completed the map exercise.

VOCABULARY

Bot•an•y - the systematic study of plants or the plant life of a particular region or district.

Co•or•di•nates - the latitude and longitude numbers that express location as a point on a map.

Ge•ol•o•gy - the systematic study of the origin, history, and structure of the Earth; the structure of a specific region of the Earth's surface.

Hy•drog•ra•phy (adj. hy•dro•graph•ic) - the systematic study of physical conditions, boundaries, flow, and related characteristics of surface waters, such as oceans, lakes, and rivers.

La•ti•tude - the angular distance around the globe north and south of the equator (0°).

Lon•gi•tude - the angular distance around the globe east and west of the prime meridian (0° longitude).

Min•ute - one sixtieth of the distance between two lines of latitude or longitude.

Na•tur•a•list - a person who studies natural objects and organisms along with their evolution, origins, and interrelationships.

Pa•le•on•tol•o•gy - the systematic study of fossils.

Zo•ol•o•gy - the systematic study of animals or the animal life of a particular region or district.

A. Introduction

Remind students that Charles Darwin served as naturalist on a voyage of the H.M.S. *Beagle*, under the command of Captain Robert FitzRoy. FitzRoy's assignment was to perform a hydrographic survey of the coasts of southeast and southwest South America and to circumnavigate the Earth. Darwin's responsibility was to gather data on geology, botany, zoology, and paleontology. The voyage took almost five years, setting sail from Falmouth, England, on December 27, 1831, and returning to Falmouth on October 2, 1836.

TEACHER TAKE NOTE

If students have read the biographical sketch in Unit One, Master 1.3a, they will already be familiar with the voyage of the *Beagle*.

B. Lesson Development

1. Review or explain latitude and longitude and how to plot coordinates on a map. (See lesson 4.1 on absolute and relative location.)

2. Distribute student copies of both the worksheet (Master 4.4b) and the world map (Master 1.2a). Allow time for students to glue the two map sections together.

3. Working as a class, in small groups, or individually, have students locate the coordinates and transfer the numbers from the worksheet to their maps. (If you work as a class, you may wish to project a transparency of the map.)

4. Distribute atlases or world maps. Using the list of coordinates and the reference materials, have students find the sites they have numbered and write the correct place names both on their maps and next to the numbers on Master 4.4b.

5. Have students use a colored pen or pencil to connect the points they have located on the map, roughly tracing the voyage of the *Beagle*.

C. Conclusion

Have students check their answers and discuss any that caused problems. Then read aloud some of Darwin's observations on the various sites from Master 4.4a This will help students to see the Galápagos in the context of the *Beagle*'s round-the-world voyage.

TEACHER TAKE NOTE

Numbers marked with an asterisk on the worksheet, Master 4.4b, call for locations that may not be in some classroom atlases. You may allow elementary-age students to skip those numbers or offer extra credit to students who locate them.

Adaptations

For younger students

You may wish to reduce the number of sites for elementary students. However, be sure to include enough to give a good sense of the *Beagle*'s route.

For older students

Have students use the map scale to approximate the number of kilometers the *Beagle* traveled.

Teacher Background Reading

From Charles Darwin's Journals

The passages that follow are Darwin's observations on some of the places the Beagle visited. Share them with students as a way of enriching the worksheet exercise. The numbers preceding the master coordinates correspond to locations on the student worksheet, Master 4.4b.

2. 16°N 24°W ________________________

On the island he commented: *The Volcanic fire of past ages & the scorching heat of the tropical sun have in most places rendered the soil sterile & unfit for vegetation.* But elsewhere his notes read: *Here I first saw the glory of tropical vegetation.*

4. 13°S 38°W ________________________

Biological diversity: Darwin comments on the great variety of plants and animals in the tropics—much greater than that of the middle and polar latitudes. *The delight one experiences in such times bewilders the mind. If the eye attempts to follow the flight of a gaudy butter-fly, it is arrested by some strange tree or fruit; if watching an insect one forgets it in the stranger flower it is crawling over. If turning to admire the splendour of the scenery, the individual character of the foreground fixes the attention.*

5. 25°S 43°W ________________________

Biological diversity: In a forest outside the city: *In these is well represented the infinite numbers of lianas* [clinging roots] *& parasitical plants & ... the contrast of flourishing trees with the dead & rotten trunks.* On a sandy plain: *The number of beautiful fishing birds such as Egrets, Cranes &c & the succulent plants assuming such fantastical forms... The few stunted trees were loaded by parasitical plants, amongst which the beauty & delicious fragrance of some of the Orchidaceae* [orchids] *were most to be admired.* In another forest: *...enormous conical ants nests, which in height were about 12 feet.* [D. admired and noted a vast number of] *fresh water animals with which every ditch abounds* [and] *obtained vast numbers of insects, many closely allied* [related to each other].

7. 39°S 62°W ________________________

(Across the pampas) Paleontology: FitzRoy wrote: *My friend's attention was soon attracted to some low cliffs near Point Alta, where he found some of those huge fossil bones, described in his work....* [Here Darwin unearthed for the first time the fossilized remains of enormous animals that he recognized at once as being similar in form but much larger than those that currently lived in the area. (editor, *Beagle Diary*, 106)]

Darwin was astonished by how much the American continent must have changed over millions of years: *Formerly it must have swarmed with great monsters: now we find mere pygmies, compared to* [the remains of their ancestors]... *The greater number, if not all, of these extinct quadrupeds* [four-footed animals] *lived in the most recent past and some of the shell fish I saw in the waters also lived at the same time as the large quadrupeds, because their fossils occupied the same rock formations...Since they lived, no very great change in the form of the land can have taken place. What, then, has exterminated so many species and whole genera* [classes]?... *An examination...of the geology...leads to the belief that all the features of the land result from slow and gradual changes.* (*The Voyage of Charles Darwin*, extract from his journal)

14. 33°S 72°W ________________________

This day has been remarkable...for the most severe earthquake which the oldest inhabitants remember. Further up the coast, closer to the epicenter of the quake, Darwin received reports of a tidal wave and saw great evidence of its destruction. He also experienced considerable aftershocks. (*Voyage*, extract from his journal) *The most remarkable effect of the earthquake was* [that it had elevated the land around the Bay of Concepcion from two to three feet]...*At the island of Santa Maria (about thirty miles distant) the elevation was greater.* [The trip was from 33°S 72°N to 33°S 69°W and back via the Portilla Pass on muleback.] *At one point Captain FitzRoy found beds of putrid mussel shells still adhering to the rocks ten feet above the high water mark: the inhabitants had formerly dived at low-water spring-tides for these shells.*

17. 2°N-3°S 87°-90°W________________________

Zoology and geology: *The black rocks heated by the rays of the Vertical sun like a stove, give the air a close & sultry feeling. The plants also smell most unpleasantly.... These islands appear paradises for the whole family of Reptiles. The black Lava rocks on the beach are frequented by large (2-3 ft) most disgusting, clumsy Lizards. When on shore I proceeded to* [collect plant specimens and] *obtained 10 different flowers;* [they are] *such insignificant, ugly little flowers, as would better* *become an Arctic, than a Tropical country.* [The land] *surface has been aptly compared to a sea petrified in its most boisterous moments. No sea however presents such irregular undulations—nor such deep & long chasms...There are large circular pits, from 30 to 80 ft deep; which might be mistaken for Craters, but are in reality formed by the subsidence* [collapse] *of the roofs of great caverns, which probably were produced by a volume of gaz* [sic] *at the time when the Lava was liquid.* (*Diary*, excerpt from his later notes on this site)

...When I see these Islands in sight of each other and possessed of but a scanty stock of animals, tenanted by these birds but slightly differing in structure & filling the same place in Nature, I must suspect they are only varieties.

From the *Diary*: *We here have another large Reptile in great numbers—it is a great Lizard, from 10-15 lb in weight & 2-4 ft in length...They have a ridge & spines along the back; are colored an orange yellow, with the hinder part of the back brick red—They are hideous animals...*

Voyage, extract from his journal: *Most of* [the plants and animals I have observed seem to be] *found nowhere else: there is even a difference between the inhabitants of the different islands. Yet all show a marked relationship with those of America... The archipelago is a little world within itself, or rather a satellite attached to America* [from which it has received a few stray animals and plants, and as different as they might appear, they seem to be related to those of the mainland].

18. 17°S 148°W ______________________

Atoll formation: We *paddled for some time about the reef admiring the pretty branching Corals.* [Darwin describes how he thinks coral atolls have been formed.]

Note: These passages have been taken from *Charles Darwin's Beagle Diary*, R. D. Keyes, Editor, Cambridge: Cambridge University Press, 1988, and *The Voyage of Charles Darwin*, Writings selected by Christopher Ralling, New York: Mayflower Books, Inc., 1979. With a few exceptions, the editor has kept Darwin's own formal, somewhat indirect prose, odd punctuation, abbreviations, and capitalization, all typical of educated writers of the time. Brackets indicate definitions and sections that have been rewritten for clarity.

Charles Darwin's Journey: A Mapping Worksheet

Charles Darwin's voyage on the Beagle was not a smooth loop around the world. The little ship often retraced its route and visited the same places twice. This activity will give you some highlights of the voyage and a feeling of how far Darwin traveled during almost five years on land and sea. It includes four of Darwin's inland excursions, two by horseback, one by mule, and one by small boat.

Directions: *Locate the places closest to the following coordinates on the blank world map (Master 4.4c) you glued together. Write the number of the item from this sheet (1., 12., 20.) in each location. When you have found them all, use a world atlas or maps to learn the names of the places Darwin visited. Enter those names near the coordinates on your map. Also enter the names in the blanks on this sheet.*

1. 50°N 5°W
2. 16°N 24°W
3. 8°S 35°W
4. 13°S 38°W
5. 25°S 43°W
6. 35°S 58°W
7. 39°S 62°W

*8. 48°S 66°W

9. 52°S 60°W
10. 54°S 68°W
11. 44°-46°S 74°W
12. 42°S 73°W
13. 39°S 74°W
14. 33°S 72°W
15. 20°S 70°W
16. 12°S 77°W
17. 2°N-3°S 87°-90°W
18. 17°S 148°W

*19. 35°S 174°E

20. 34°S 151°E
21. 43°S 147°E

*22. 33°S 118°E

23. 20°S 57°E
24. 34°S 18°E

*25. 16°S 6°W

26. 8°S 14°W
27. 13°S 38°W
28. 16°N 24°W
29. 40°-43°N 25°-31°W
30. 38°-39°N 5°W

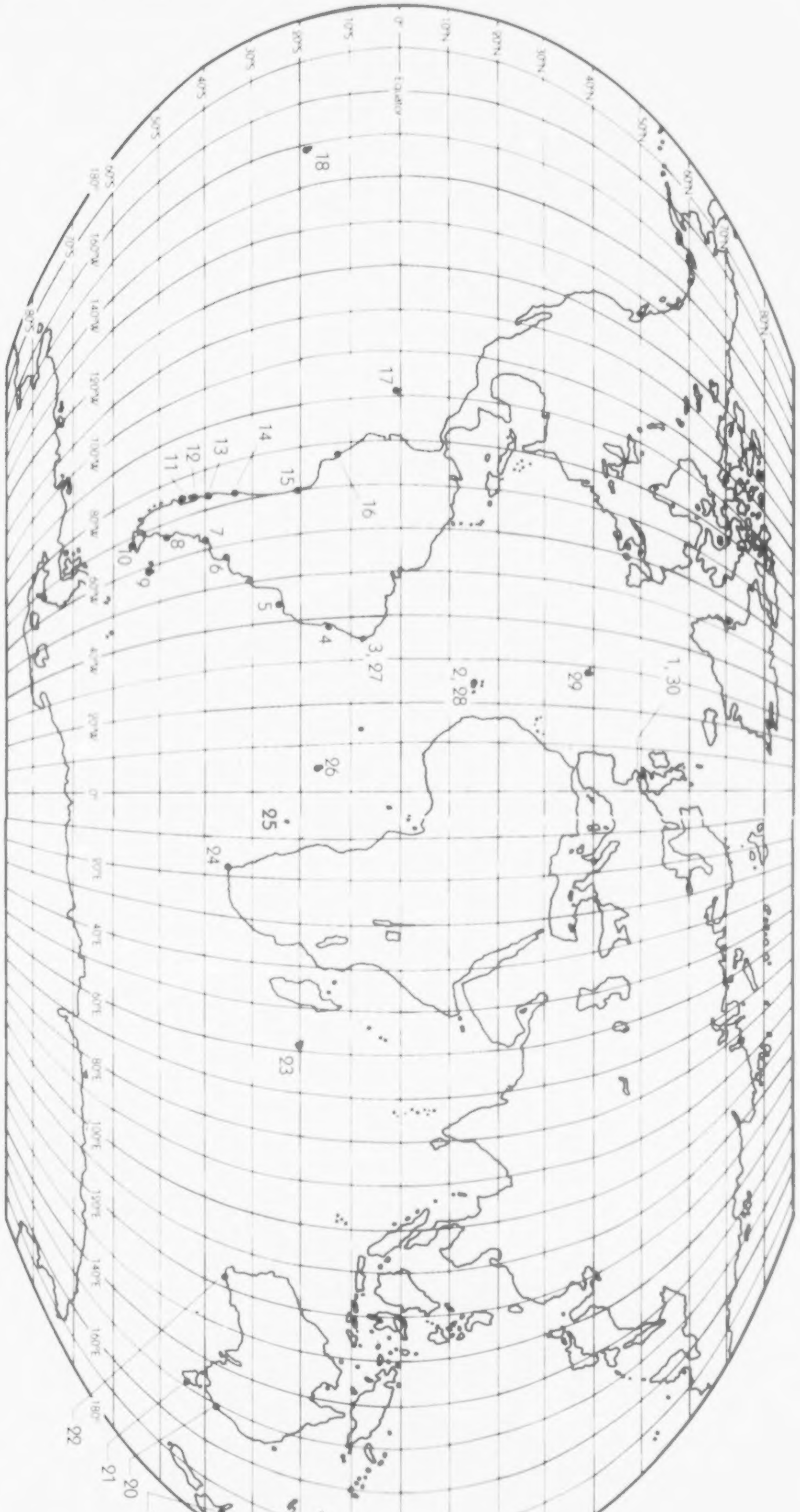
Back of Master 4.4b

Answer Key

1.	50°N 5°W	Falmouth, England
2.	16°N 24°W	Cape Verde Islands
3.	8°S 35°W	Recife (Pernambuco)
4.	13°S 38°W	Salvador (Bahia)
5.	25°S 43°W	Rio De Janeiro
6.	35°S 58°W	Buenos Aires (on horseback across the Pampas to #7)
7.	39°S 62°W	Bahia Blanca
8.	48°S 66°W	Deseado (Port Desire)
9.	52°S 60°W	Falkland Islands
10.	54°S 68°W	Tierra del Fuego
11.	44°-46°S 74°W	Chonos Archipelago
12.	42°S 73°W	Chiloe Island
13.	39°S 74°W	Valdivia
14.	33°S 72°W	Valparaiso (on muleback across to Mendoza and back via Portillo Pass)
15.	20°S 70°W	Iquique
16.	12°S 77°W	Callao
17.	2°N-3°S 87°-90°W	Galápagos Islands
18.	17°S 148°W	Tahiti
19.	35°S 174°E	Russell, New Zealand
20.	34° 151°E	Sydney, Australia
21.	43°S 147°E	Hobart (Tasmania), Australia
22.	33°S 118°E	Albany, Australia
23.	20°S 57°E	Mauritius
24.	34°S 18°E	Cape of Good Hope
25.	16°S 6°W	St. Helena
26.	8°S 14°W	Ascension
27.	13°S 38°W	Salvador
28.	16°N 24°W	Cape Verde Islands
29.	40°-43°N 25°-31°W	Azores
30.	38°-39°N 5°W	Falmouth, England

Answer key to Darwin's Journey

MASTER
4.4c


Equator
1, 30
2, 28
3, 27
4
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26
29

TRAVELING WITH JJ
(Movement)

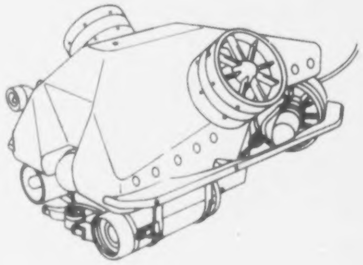
4.5

Rationale Jason Jr. (JJ) is housed at the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Many scientists and engineers work together to prepare JJ for a trip to the Galápagos Islands. In this lesson students will trace JJ's route from Woods Hole to the Galápagos Islands.

Objectives Students will:

Trace JJ's route from Woods Hole, Massachusetts, to Guayaquil, Ecuador, and then to the Galápagos Islands.

Consolidate their knowledge of geography by asking and answering questions about the route JJ will travel.



Materials

- Classroom map of the United States or Master 4.1a, The United States and Southern Canada
- Transparency made from Master 4.4c, World Map with Coordinates, left side only
- Overhead projector

For each group of three to four students:

- Master 4.5a, Galápagos Game Board (two pages)
- Master 4.5b, JJ Playing Pieces
- Poster board or construction paper
- Scissors, thumb tacks, and tape for making markers
- Master 4.5c, Galápagos Question Cards (three pages plus one sheet of blanks)
- Four marking pens or crayons: one red, one yellow, one blue, and one green

TEACHER TAKE NOTE

You may write your own questions on the sheet of blank cards, or invite students to make up their own. (See Adaptation.)

Procedure

Teacher Preparation

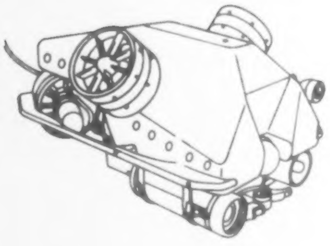
Before class, copy as many sets of materials (Masters 4.5a, 4.5b, and 4.5c) as you will have groups. Cut apart the question cards. Either at home or in the previous class period, have students glue their copies of Master 4.5b, Jason Jr. Game Pieces, to poster board or construction paper. They may then cut out and assemble the playing pieces.

A. Introduction

Explain to the students that JJ travels with four large trailers or vans, each roughly 7 meters x 2.5 meters x 2.5 meters (about 22 feet x 8 feet x 8 feet). The first, the production van, contains equipment that is needed to produce the downlink site transmissions. Vans two and three will be hooked together as one big van once they have been hoisted onto the Ecuadorian Park Service's ship *Tohalli*. These vans will house the microwave sending and receiving site, land-based sites, diver communication equipment, and JJ's control apparatus. The fourth van will have the antennae, transmitters, receivers, and telephones.

JJ's traveling companions include seven scientists and naturalists, six camera operators, four sound and microwave specialists, a producer, a director, a technical director, an associate director, an editor and prompter operator, three satellite specialists, eight members of a support team, a qualified scuba diver, and a logistics support officer. Some of these people will come from Woods Hole Oceanographic Institution, but others will come from other parts of the United States and from countries in South America.

B. Lesson Development



1. Ask students what they must acquire from the U.S. State Department and keep with them at all times when traveling in most foreign countries. (passports) The JASON Project crew must also have passports, and before the trip begins, must have an export license for JJ and customs papers listing everything contained in all the vans.

2. Draw four big rectangles on the chalkboard and tell the students that they represent the JASON vans. Ask: How could these vans be moved? Explain that forklifts place the vans onto trucks which take them to a long-distance trucking company near Boston. The vans are then placed on air-ride trucks for travel to a major shipping terminal.

3. Have the students look at a map of the United States and name some major shipping terminals to which JJ and the rest of the equipment might be sent. Accept the name of any large coastal city as a correct answer. JJ will actually be placed on a ship in New Orleans, Louisiana. Trace the route from Boston to New Orleans on the U.S. map.

4. Project the left half of Master 4.4c, World Map with Coordinates, and have students trace the expedition's route from New Orleans to Ecuador. Ask students to name the countries to the east and west of the route and the canal through which the ship must pass. Have them find Ecuador on a map and name its capital (Quito—population approximately 920,000) and its largest city (Guayaquil—population approximately 1,250,000).

5. Explain that once the ship reaches Guayaquil, Ecuador, large cranes will remove the vans from the cargo ship and place them onto a research ship, the *Tohalli*. This will be the flagship for JJ's equipment and home for some of the people who work on the JASON Project. It will be anchored 10 to 20 meters (33 to 66 feet) out in protected waters. This ship will

not accommodate all the JASON team, so three other ships will also be used. Now trace the *Tohalli*'s route from Ecuador to the Galápagos.

C. Conclusion

Divide the class into groups of three or four. Provide each group with a copy of the game board, a set of question cards, four playing pieces, and four crayons or marking pens.

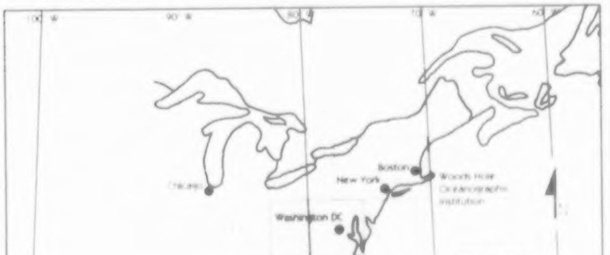
Tell the students that they will travel with JJ from Woods Hole, Massachusetts, to the Galápagos Islands. They will be traveling by land and sea. Read the directions on the game board with the students.

Before beginning the game, have each of the students in each group select a pen or crayon (red, green, blue, or yellow) and color his or her marker. To determine who takes the first turn in the game, call out the name of a color. In every group, the student with the color you called draws the first card. The first student to arrive in the Galápagos is the winner.

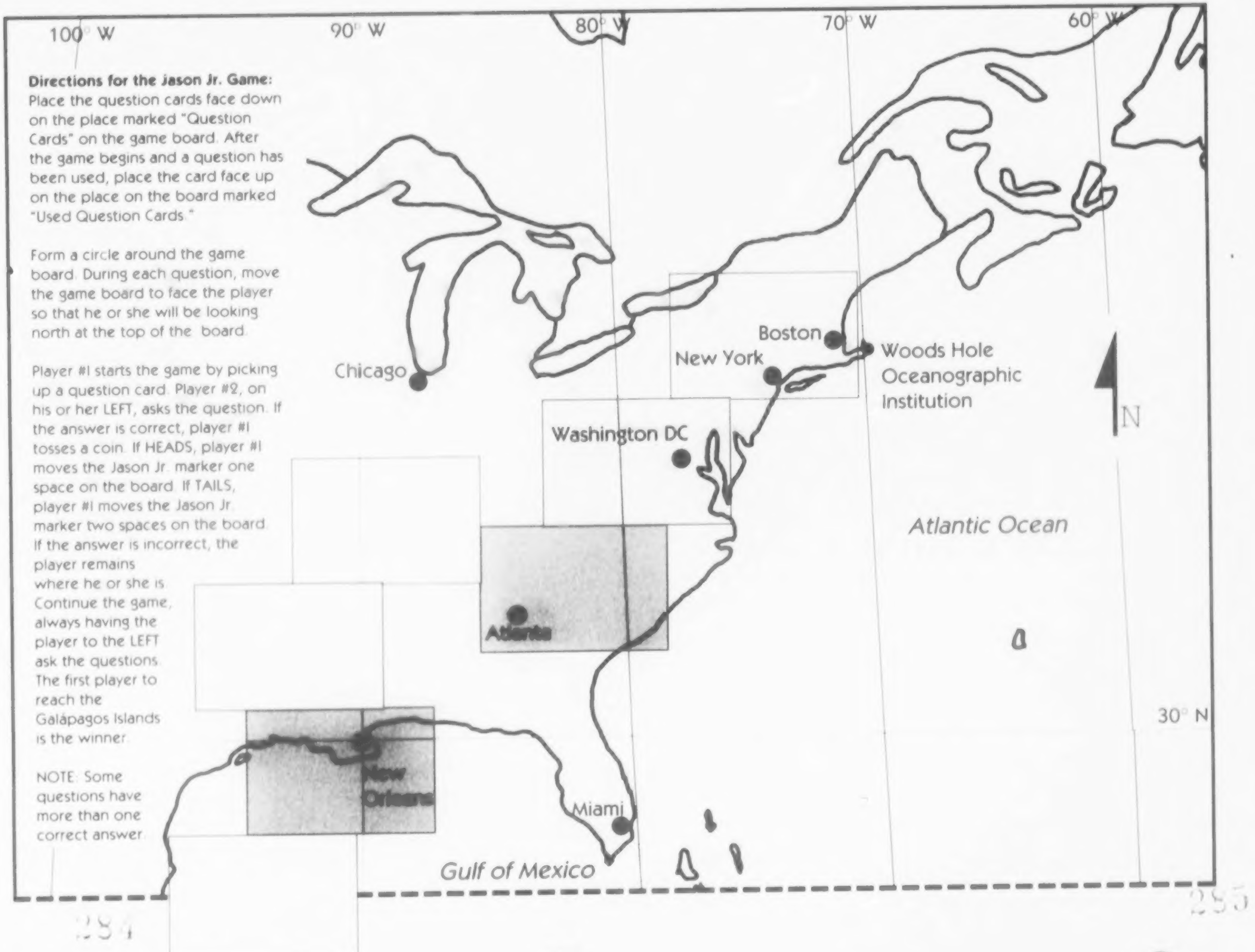
Adaptation

For all ages

Invite students to write their own questions on the sheet of blank cards and add those to the game. Make extra copies when you prepare the game pieces.


100°W
90°W
80°W
70°W
60°W
Chicago
Boston
New York
Woods Hole Oceanographic Institution
Washington DC
Atlanta
Atlantic Ocean
30°N
New Orleans
Miami
Gulf of Mexico
question cards
used question cards

Galápagos Game Board



Directions for the Jason Jr. Game: Place the question cards face down on the place marked "Question Cards" on the game board. After the game begins and a question has been used, place the card face up on the place on the board marked "Used Question Cards."

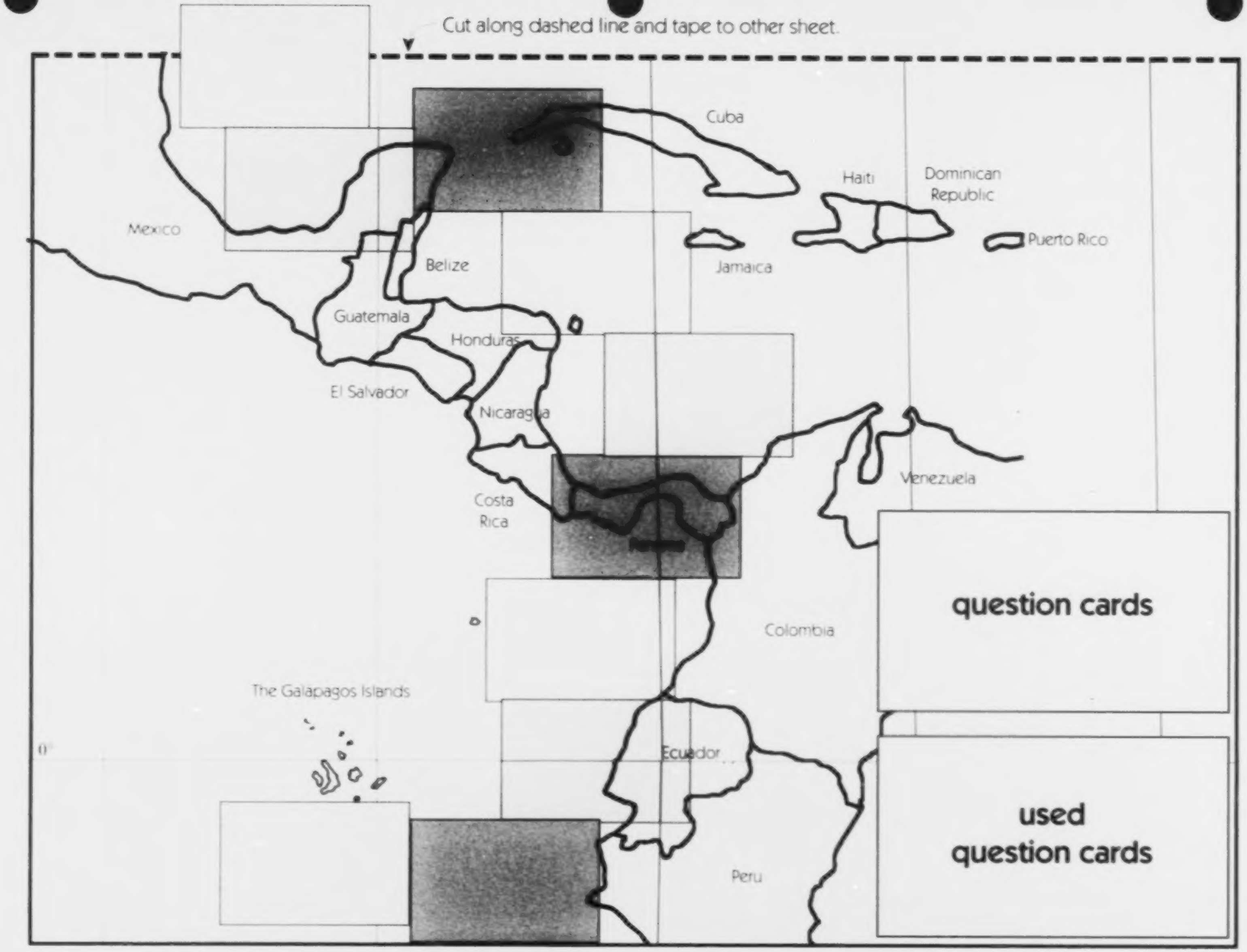
Form a circle around the game board. During each question, move the game board to face the player so that he or she will be looking north at the top of the board.

Player #1 starts the game by picking up a question card. Player #2, on his or her LEFT, asks the question. If the answer is correct, player #1 tosses a coin. If HEADS, player #1 moves the Jason Jr. marker one space on the board. If TAILS, player #1 moves the Jason Jr. marker two spaces on the board. If the answer is incorrect, the player remains where he or she is. Continue the game, always having the player to the LEFT ask the questions. The first player to reach the Galápagos Islands is the winner.

NOTE: Some questions have more than one correct answer.

100° W
90° W
80° W
70° W
60° W
Chicago
Boston
New York
Woods Hole Oceanographic Institution
N
Washington DC
Atlantic Ocean
Atlanta
30° N
New Orleans
Miami
Gulf of Mexico
284
285

Master 4.5a, Continued


Cut along dashed line and tape to other sheet.
Cuba
Haiti
Dominican Republic
Puerto Rico
Jamaica
Mexico
Belize
Guatemala
Honduras
El Salvador
Nicaragua
Costa Rica
Venezuela
Colombia
The Galapagos Islands
0°
Ecuador
Peru
question cards
used question cards

BEST COPY AVAILABLE

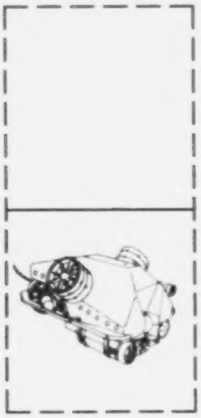
MASTER
4.5 b

Jason Jr. Game Pieces

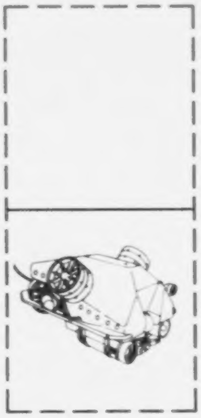
Directions for assembling game pieces:

1. Color each marker the indicated color.
2. Cut out each piece along the dashed line.
3. Fold the piece at the solid line, so that JJ faces out. The piece should now stand as an inverted V.
4. Make a loop out of tape and attach it to the inside of the piece on the back of the leg that has JJ on it.
5. Place a thumbtack through the tape, pointing at the fold of the V.
6. Press the other leg of the V against the tape. The base of the tack serves as the stand for the game piece.

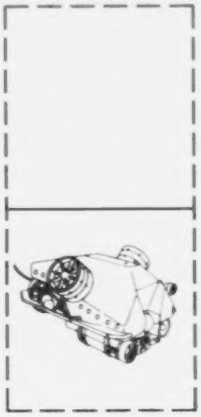
Blue



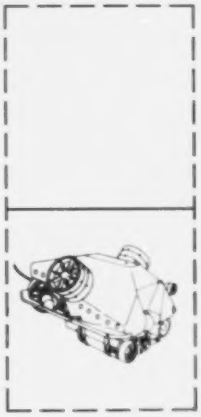
Green

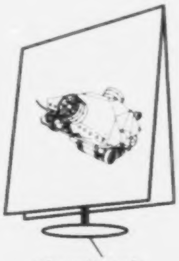


Yellow



Red





Galapágos Question Cards

[Answers are in brackets]

Galápagos Islands Question Cards

If you were to travel directly south from Woods Hole on Cape Cod along the 70° West longitude line to Ecuador, what land would you reach before getting to the coast of South America?

[Dominican Republic]

Galápagos Islands Question Cards

In what country would you land when you reached the coast of South America?

[Venezuela]

Galápagos Islands Question Cards

If you continued south on the continent of South America along the 70° West longitude line, what direction would you take to reach Ecuador?

[west or southwest]

Galápagos Islands Question Cards

What is important about the location of the Galápagos Islands on the world map?

[They lie on and near the equator.]

Galápagos Islands Question Cards

On what line of latitude is the equator?

[0°]

Galápagos Islands Question Cards

If you were to travel by land from Woods Hole to New Orleans with Jason Jr., in what direction would you be traveling?

[southwest]

Galápagos Islands Question Cards

After you ship out from New Orleans to Ecuador, over which large water bodies would you travel? Name at least two.

[Gulf of Mexico, Caribbean Sea, Pacific Ocean]

Galápagos Islands Question Cards

Name two or more of the major landform regions you would cross from Woods Hole to New Orleans.

[Atlantic Coastal Plain, the Piedmont, the Appalachians, the Gulf Coastal Plain]

Galápagos Islands Question Cards

Of what ocean are the Gulf of Mexico and the Caribbean Sea a part?

[Atlantic Ocean]

Galápagos Islands Question Cards

As the ship carrying Jason Jr. sails along the coast of Central America, what countries will it pass? (Name at least three)

[Mexico, Belize, Honduras, Nicaragua, Costa Rica , Panama]

Galápagos Islands Question Cards

Through which country will the cargo ship hauling Jason Jr. pass on its way to the Galápagos?

[Panama]

Galápagos Islands Question Cards

What is the largest island in the Caribbean Sea?

[Cuba]

Galápagos Islands Question Cards

What is the approximate distance from the west coast of Ecuador to the Galápagos?

[600 miles (1000 km.)]

Galápagos Islands Question Cards

What English scientist made the Galápagos Islands famous because of the visit and observations he made there in 1835?

[Charles Darwin]

Galápagos Islands Question Cards

What forces within the Earth's surface created the Galápagos Islands?

[volcanic eruptions or volcanism]

Galápagos Islands Question Cards

What geographic term do we use to identify a group of islands located near each other and sharing common geological features?

[archipelago]

Galápagos Islands Question Cards

When Jason Jr. explores the waters of the Galápagos, what two marine reptile species will it see in significant numbers?

[green turtles and marine iguanas]

Galápagos Islands Question Cards

What is the capital of the country that owns the Galápagos?

[Quito]

Galápagos Islands Question Cards

What is the largest city in Ecuador?

[Guayaquil]

Galápagos Islands Question Cards

What is the name given to a person who studies volcanoes and landforms created by volcanoes?

[volcanologist or geologist]

Galápagos Islands Question Cards

What is the name given to a person who studies living matter in all its forms?

[biologist]

Galápagos Islands Question Cards

What is the name given to the person who will be filming and taking pictures of Jason Jr?

[camera operator]

Galápagos Islands Question Cards

Name two big pieces of equipment that will be used to move Jason Jr.'s vans.

[forklift and crane]

Galápagos Islands Question Cards

What is the name of the ship from which Dr. Ballard and his crew will be broadcasting?

[Tohalli]

Galápagos Islands Question Cards

Why do we call the imaginary line between the North and South Poles the equator?

[because it divides the Earth into two equal hemispheres]

Galápagos Islands Question Cards

What is the study of the surface of the Earth and how people use the Earth?

[geography]

Galápagos Islands Question Cards

If you were to fly from Woods Hole to Guayaquil, Ecuador, how far would you fly? Choose one of the following: 1600 kilometers (1000 miles); 3200 kilometers (2000 miles) ; or 4800 kilometers (3000 miles)

[4800 kilometers (3000 miles)]

Galápagos Islands Question Cards

If your plane averaged 1000 km (600 miles) per hour, how many hours would it take you to reach Guayaquil from Woods Hole?

[5 hours]

Galápagos Islands Question Cards

Would you gain or lose time if you traveled to Ecuador by changing time zones?

[neither, because Ecuador is in the same time zone as Woods Hole]

Galápagos Islands Question Cards

Which articles of clothing would you not need if you were to visit the Galápagos? winter parka, snow boots, sweater, woolen scarf, fur gloves, hiking boots

[all of the above]

Galápagos Islands Question Cards

Galápagos Islands Question Cards

Galápagos Islands Question Cards

Galápagos Islands Question Cards

Galápagos Islands Question Cards

Galápagos Islands Question Cards

Galápagos Islands Question Cards

Galápagos Islands Question Cards

4.6

GROWING UP IN THE GALÁPAGOS

(Human-Environmental Interaction, Regions)

Rationale

By sharing details about the everyday life of young people in the Galápagos, students will gain a sense of what it would be like to live there.

VOCABULARY

Sub•sis•tence - a quality of life that includes only the barest essentials. *Subsistence farming* is farming to eat, with little or no surplus to sell.

Objectives

Students will:

Evaluate data describing the culture of the towns and villages of the Galápagos.

Describe the everyday activities of young people living in a town or village on the small island of Santa Cruz, over 1000 km (600 miles) from the mainland of Ecuador.

Decide whether or not to classify the Galápagos as a cultural region. Discuss why it is sometimes difficult to define a region.

Materials

- Transparency made from Master 4.6a, Santa Cruz Island
- Transparency made from Master 4.6b, Puerto Ayora, Santa Cruz Island
- Overhead projector
- Master 4.6c, Cultural Inventory of Settled Communities in the Galápagos Islands

Procedure

A. Introduction

Explain to the class: According to the best evidence we have, no humans visited the Galápagos islands until the 16th century. When European exploration began in that century, pirates, seal hunters, whalers, warriors, and scientists visited the islands. In the period from the 1830s until about 40 years ago, several groups attempted to establish settlements, but few were successful, and the islands remained sparsely populated. Within the last four or five decades, however, immigrants, mostly Ecuadorian, have established permanent settlements, and today the population exceeds 10,000. Puerto Ayora, the largest population center, now has the rhythms of life and the variety of human activities typical of all settled communities. Many children have been born on the island of Santa Cruz (*Isla Santa Cruz*) where Puerto Ayora is located, and have spent their growing-up years on this small island.

Settled communities have flourished in the Galápagos within the last 50 years largely because the government of Ecuador has established a center for scientific investigation. The unique plants and animals of these islands aroused the interest of many scientists. Later, as modern transportation made the islands easily accessible to tourists, tourist agencies have sprung up, and tourism has become a business.

Previously the only economic activities consisted of subsistence farming and a small fishing industry. Because the islands are a province of Ecuador, the culture and customs of the people are very much like those of the mainland. There are differences, however. The distance from Ecuador, the resulting isolation with respect to supplies, construction materials, and vehicles, and the economic and cultural influences of international tourism have created a style of living clearly separate from that of the mainland. Growing up in such a place is quite different than growing up in the United States, or even in mainland Ecuador. To understand the Galápagos Islands fully, we need to know how the inhabitants live—at home, at school, at work, and at play.

B. Lesson Development

1. Project Master 4.6a, Santa Cruz Island, and ask students to describe its physical appearance. Tell them that Santa Cruz Island (*Isla Santa Cruz*) will be the focus of this activity. It is a small island—only 986 sq km (380 square miles) in area—about one-third the size of the state of Rhode Island. Its highest elevation is 864 meters (2,835 feet) above sea level. Parts of the island are high enough to experience climates warmer and more humid than the coastal lowlands.

Point out that Santa Cruz is in the center of the archipelago, and thus conveniently located for both scientific investigations and tourist excursions to the other islands. About 5,000 people live on the island, two-thirds of them in Puerto Ayora. The rest are in the farming villages of Bella Vista and Santa Rosa. Both are at higher elevations, where the soil is more fertile and the humidity more intense than along the coast at Puerto Ayora.

Project the transparency of Master 4.6b, Puerto Ayora and Santa Cruz Island. Allow the class some time to study the map. Then ask them to suggest some terms that describe the character of the town. They are likely to offer descriptions such as *small, confining, coastal, crowded, quaint,* and *isolated*. Explain that this map is not drawn to scale. The entire island is only about 40 km (25 miles) from north to south at its widest point.

2. Divide the class into groups of three or four and distribute copies of Master 4.6c, Cultural Inventory of Settled Communities in the Galápagos Islands. Tell the groups that they are to study the inventory carefully to develop a sense of what it is like to live in Puerto Ayora. Encourage the members of each group to share their reactions to the items in the inventory and to discuss what they consider the good points and bad points of living in the town.

TEACHER TAKE NOTE

Before examining life in the Galápagos, have students compare their own experiences. Poll the class to find out how many students have spent time in country or rural environments, as opposed to cities or suburbs. Ask if any students were raised near the sea or on an island. This will give students a reference point from which to look at a community in the Galápagos.

3. When the groups have completed their discussions, have all the students share their opinions, especially as they relate to the question: What is it like to grow up in the Galápagos? Invite students to make comparisons between their own experience and that of their counterparts in the Galápagos. Have them pay particular attention to the simplicity of a small town in an isolated setting with no daily newspapers, library, scheduled television programming, high technology items (like computers and microwave ovens), fast food franchises, or closely kept schedules, but with advantages like being able to buy fresh bread at the bakery every afternoon, minimal traffic, a low crime rate, and the freedom to visit and use nearby facilities such as the beach, the national park, and the Darwin Station.

TEACHER TAKE NOTE

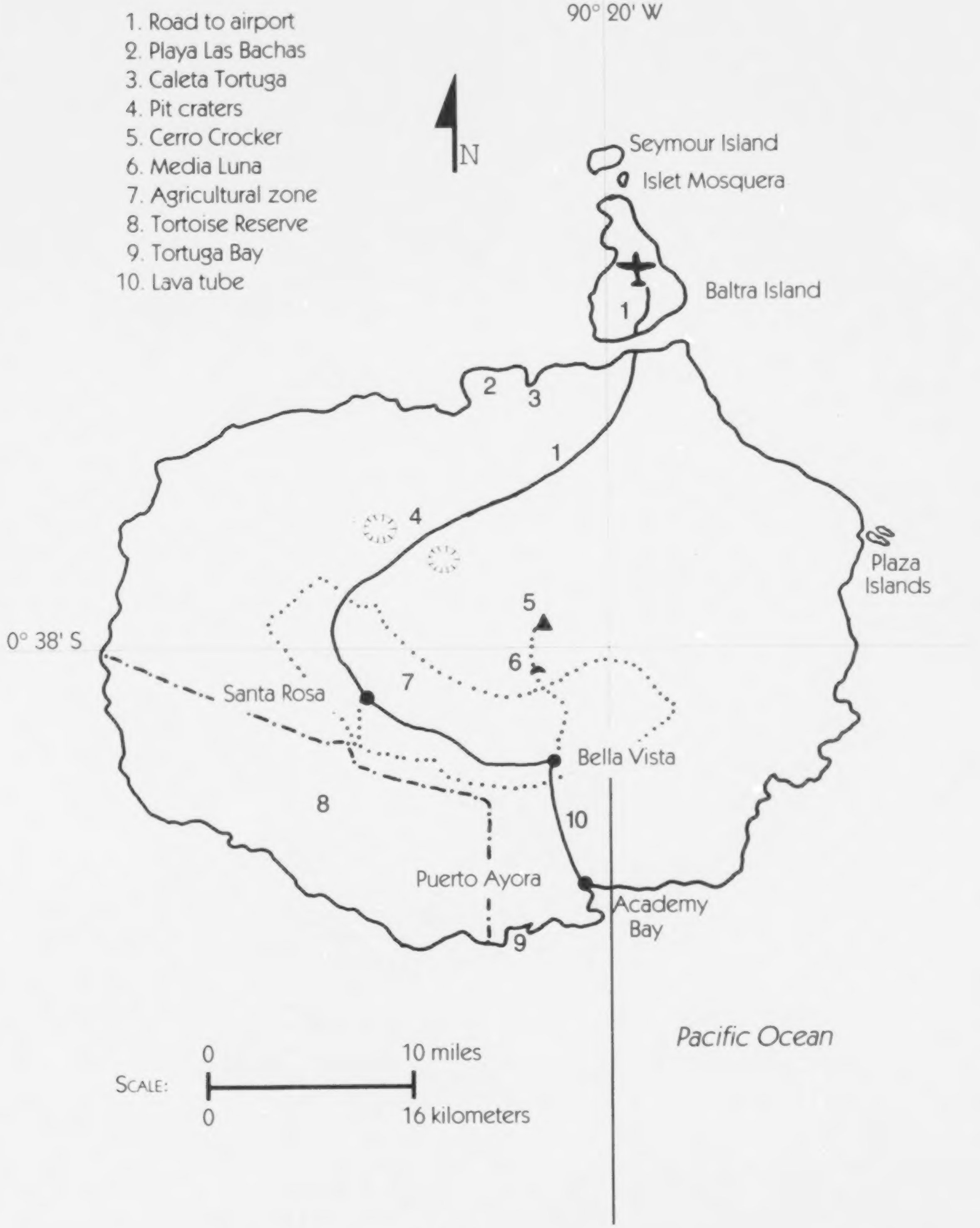
Emphasize that communities in the Galápagos will not all be the same. There will be differences, for example, between the farming communities in the highlands and the major town. It is important that the students do not view the inhabitants as primitive or their culture as less developed than ours.

C. Conclusion

Remind the class that in order to make the world understandable to us, geographers divide it into regions. Defining a region is one way of simplifying the great diversity of our world. If the parts of an area have more in common with each other than with the areas surrounding it, we can define that area as a region. (A city, for example, has many different neighborhoods within it, but as a *type* of settlement it is different from rural areas.)

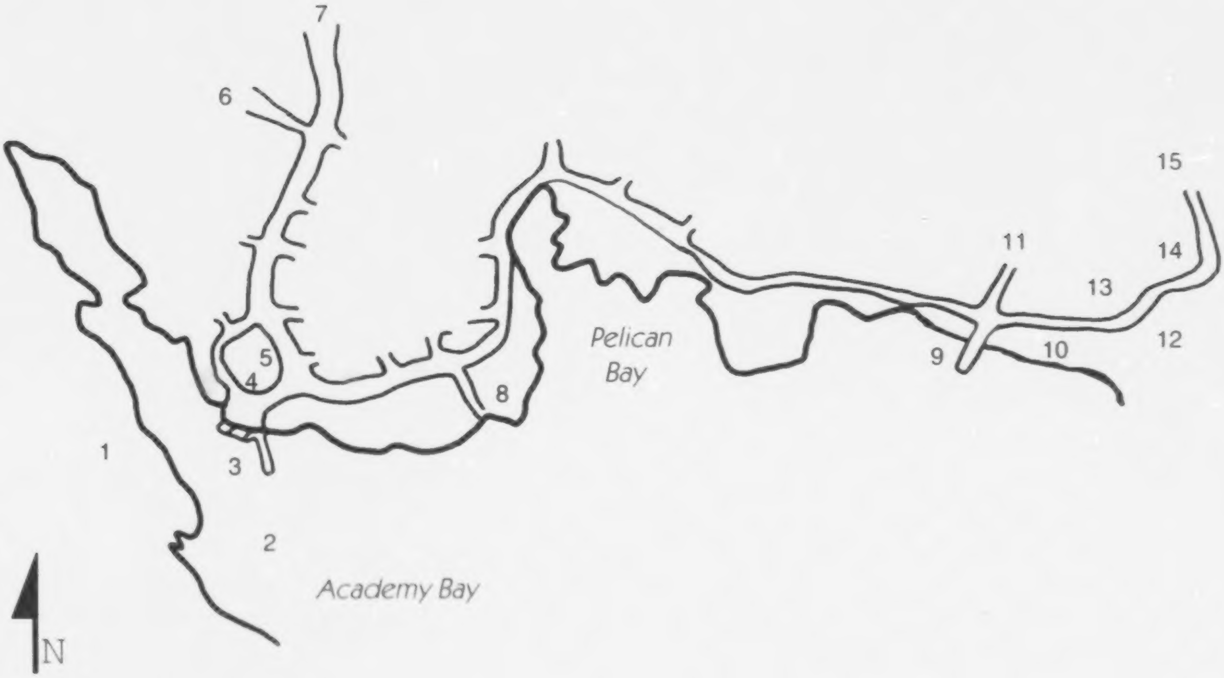
Regions may be based upon physical or cultural characteristics or on combinations of the two. Because of its distinctive physical environment, along with its unique plants and animals, it is clear that we can define the Galápagos as a separate physical region. Ask students to draw from what they discussed in their small groups to explain why the islands are a cultural region as well. The discussion should focus on the common characteristics found among the people of Santa Cruz, especially as revealed in the cultural inventory. These characteristics include: language; religion; history and experience; economic activities (ways of earning a living); schooling; food and diet; celebrations and holidays; recreation; patterns of daily living; and physical appearance of the towns.

Santa Cruz Island


1. Road to airport
2. Playa Las Bachas
3. Caleta Tortuga
4. Pit craters
5. Cerro Crocker
6. Media Luna
7. Agricultural zone
8. Tortoise Reserve
9. Tortuga Bay
10. Lava tube
90° 20' W
N
Seymour Island
Islet Mosquera
Baltra Island
Plaza Islands
0° 38' S
Santa Rosa
Bella Vista
Puerto Ayora
Academy Bay
Pacific Ocean
1
2
3
4
5
6
7
8
9
10
SCALE:
0
10 miles
0
16 kilometers

MASTER 4.6 b

Puerto Ayora, Santa Cruz Island (*Isla Santa Cruz*)


7
6
15
11
14
13
5
4
Pelican Bay
9
10
12
8
1
3
2
Academy Bay
N

1. Residential area
2. Anchorage
3. Town docks
4. Post office
5. Hospital
6. Trail to Tortuga
7. Road to Highlands and Baltra
8. Police
9. National Park dock
10. National Park Information
11. Galápagos National Park Service
12. Charles Darwin Research Station
13. Van Straelen Exhibit Center
14. Tortoise-raising building
15. Tortoise pens

MASTER
4.6 c

Cultural Inventory of Human Communities in the Galápagos Islands

Language

Spanish

Typical Family Dwelling

building materials
- house: cinder block, cement or lava rock (construction is more simple in the highlands)
- roof: tin
- foundation: lava
- floors: cement
- inside walls: same as outside

rooms—two or three

bottled gas stove for cooking

electric refrigerator

110-volt electric service for 18 hours per day (electricity less common in the highlands)

running cold water in house

showers and toilet in room behind the house

water for showers heated by solar energy

Transportation

walking (Students in the highlands walk farther to school than those along the coast.)

bus (Buses stop where people are waiting rather than only at scheduled stops.) Trips to Puerto Ayora are special events for people in the highlands.

car or truck (Drivers will pick up riders waiting along the side of a road.)

boat

airplane—one flight a day to Ecuador

Note: Gasoline is imported in 190 liter (50 gallon) containers and stored behind homes. There is one road on the island, and very few people own cars or trucks.

Communication

two radio stations—operated by missionaries and broadcast at alternate times

broadcast content—music, soap operas, and sometimes personal messages

TV/VCR—no television transmitting stations, but movies are available

Essential Services

police

one doctor

one basic hospital/clinic

garbage collection—regular but unscheduled

Economic Activities

cattle raising—for export

crop farming—tropical fruits and vegetables (for local use only)

fishing—*bacalao* (codfish, generally salted and dried for local consumption)

Darwin Foundation

Park Service

tourism—supplies, guides, souvenirs

Diet

breakfast—cheese, bread, and coffee

lunch—hot soup, meat or fish, rice and vegetables or fruit

dinner—about the same as lunch

Note: Residents eat what farmers grow on the island.

School Life

school day—7 am to 2 pm

kindergarten to twelfth grades housed in one building

uniforms: girls—light blue blouse, dark blue skirt, sandals

boys—shirt, black trousers, sandals

Note: The only high school classes on Santa Cruz Island are in Puerto Ayora.

Recreational/Leisure Activities

dancing and singing

movies and videotapes

visiting animals at the Darwin Center

net fishing

volleyball games

visiting relatives in the highlands

Religion/Religious Holidays

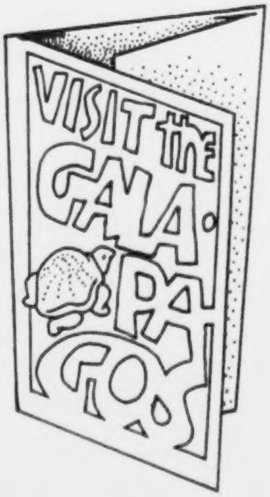
Christmas—very religious day; Santa Claus arrives by boat; some lights as decorations on houses

Mardi Gras—carnival time just before the beginning of Lent

THE GALÁPAGOS ISLANDS TOUR SERVICE

4.2

Rationale The role of tourism is a major political and economic issue in the Galápagos Islands. The islands constitute one of the most valuable and unusual national parks in the world.



Objectives Students will:

Identify the tourist attractions as well as the scientific and educational opportunities available in the Galápagos Islands.

Create a brochure that will stimulate interest in the Galápagos.

Consider assets and liabilities of tourism for small island communities.

Debate a plan to strengthen the economy of the island by encouraging tourism while controlling any possible negative effects of tourism.

Materials

- Construction paper of various colors for making brochures
- Scissors, markers, and other art materials
- Library references
- JASON journals (notebooks students have been keeping as they move through this curriculum)
- Samples of tourist promotion brochures

Procedure

Teacher Preparation

Well in advance of the day you plan to teach this lesson, arrange for a member of your local Chamber of Commerce, or other local or state government agency that promotes tourism, to address your class. Ask this individual to be prepared to describe how he or she gathers information that will convince people to travel to your area, and also to talk about the education and experience a person would need to perform this work effectively. You may also wish to invite someone from your state park agency or the National Park Service to discuss the role and importance of land areas set aside as public preserves.

Assign students to collect different types of brochures that will serve as models for the one they are going to create.

Local travel agencies should be able to supply some of these. So should the agency in your regional or state government that promotes tourism.

A. Introduction

Review Unit One, Lesson Two, and the second activity in Unit One, Lesson Three. Both deal with the role of tourism in the Galápagos Islands. Emphasize that the government of Ecuador has worked hard to preserve the islands and to keep their environment as much as possible in its natural state. In order to accomplish their scientific, educational, and recreational purposes, the Galápagos Islands should be open to the public. Tourism is also important to the economic life of the people who live on the islands. Should the government allow tourism to expand unchecked, or limit the ways in which people study and enjoy the natural environment?

B. Lesson Development

1. Introduce your guest speakers and ask them to talk about their work. Be sure to allow plenty of time for questions.

2. Invite students to share the brochures that they have gathered, along with any that your speakers provide. Instruct students to imagine themselves as members of DITURIS, the Ecuadorian government's official tourist information agency. Your task is to create a travel brochure that will encourage people to come to the Galápagos Islands, but also make them aware of the restrictions they must observe while they are staying there.

3. Divide the class into four groups. Groups One through Three will be research groups. Group Four and Group Five (to be assembled later) will be production groups.

Assign Group One to use references from the library and their JASON journals to investigate the geography and geology of the Galápagos. Their data should include a map of the islands showing their location in relation to Ecuador, to the Western Hemisphere, and to the world. The map should include the names and locations of the islands, chief towns, ports, airports, and roads, and also indicate which islands are open to visitors. These same students should gather information on the cultural and physical characteristics of the islands and their populations.

TEACHER TAKE NOTE

If necessary, provide these students with Lessons 5 and 7 in Unit Three, which contain illustrations and food webs of plants and animals.

Assign Group Two to investigate plants and animals that might be of interest to scientists. They should gather information on the types of rare native animal and plant life, their distinctive characteristics, and the research and educational facilities available.

Assign Group Three to obtain information relating to the cost of travel, lodging, food, recreation, and entertainment. This group should also find out about any restrictions that affect tourists in the Galápagos.

Group Four will be responsible for gathering appropriate maps, art, photographs, and designs to make the brochure attractive.

When the research has been completed, but groups are still assembling their notes, convene Group Five. This group will be composed of one individual selected from each of the other groups plus one student who particularly enjoys writing. These students will decide how to prepare written material for the brochure, organize the information, and then gather data from the other groups. They might organize the information according to the following outline:

- The location and geographical characteristics of the Galápagos Islands and some reasons for their attractiveness to tourists
- Interesting descriptions of the people, plants, and animals
- Important facts about the islands
- Possibilities for recreation and entertainment
- Facts about travel, lodging, and food
- Travel restrictions and any other restrictions or regulations, along with the reasons for them

Groups Four and Five will integrate text with art and present their finished product to the class, explaining why they decided to include some kinds of information and exclude others. They should then discuss with the rest of the class how successful their brochure will be, not only in attracting people to travel to the islands, but also in motivating them to respect the islands' fragile environments.

C. Conclusion

Form a debate panel by selecting one student from each research group. Panel members should choose one of the students as moderator and agree on one of the following propositions for debate:

- Ecuador should increase tourism to the Galápagos Islands in order to provide revenue for the government.
- Ecuador should restrict tourism in the Galápagos Islands.
- Ecuador should prohibit tourism in the Galápagos Islands.

Adaptation

For all ages

A second debate might be organized to discuss the same topics for the students' own state.

THE GALÁPAGOS ISLANDS IN TIME

4.8

ACTIVITY ONE

Reports from the Galápagos

My Dearest Friend
I take pen

Rationale

Until recently, human beings have been only occasional visitors to the Galápagos, but their recorded visits have spanned five centuries. These visits have involved a colorful array of characters and often played a role in larger historical events.

Objectives

Students will:

Read letters representing different periods of history in the Galápagos, from 1535 to the present.

Identify the events and act them out.

Locate the events in a chronology relating events in the Galápagos with other historical events.

Materials

- Student copies of Master 4.8a, Letters from the Galápagos
- Assorted props for role playing: hats, canes, old coats, boots, and so on
- Student copies of Master 4.8b, Chronology of the Galápagos and Selected Events in U. S., Canadian, and World History

Procedure

Teacher Preparation

Assemble a box of props from your own or the school's supplies, or ask students in advance to bring props from home. Be sure there are at least two or three items for each of the eight groups.

TEACHER TAKE NOTE

Items used as props need not be historically accurate for each or any period. They are only intended as aids to imagination.

A. Introduction

Explain to the students that although the recorded history of the Galápagos only goes back to 1535, fishermen from Ecuador and northern Peru may have visited the islands for centuries before this time. The waters were rich with fish, and the peoples of the region had vessels that could have carried them to the islands. Perhaps they came occasionally, or perhaps they came every year at the same season, but they left no written records and no artifacts that can definitely be dated to before the 16th century.

B. Lesson Development

1. Divide the class into eight groups. Distribute copies of Master 4.8a and assign each group to develop a two-minute skit based on one of the letters.

2. Allow ten minutes for each small group to read its own passage and the background provided, choose props, agree on roles, and prepare a skit. Encourage students to draw on their imaginations and previous knowledge in developing characters and action, while staying within the historical context provided.

TEACHER TAKE NOTE

Although most of these letters were written by men, students will think of many ways to introduce female characters into their presentations. At the time of Darwin's visit, for example, some of the islands were inhabited, so a conversation with a woman resident would not be out of place.

3. Invite groups to take turns presenting their skits. At the beginning of each group's presentation, ask one student to set the scene and each of the characters to introduce herself or himself. Invite questions from the class at the end of each skit.

C. Conclusion

Distribute copies of the chronology, Master 4.8b. Give students time to read it and highlight the events portrayed in class.

Adaptations

For younger students

1. Instead of duplicating all the readings for each student, cut them apart and provide students only with the piece their own group will be using. If your students are eager readers, distribute the full set and encourage them to read the full text outside of class.

TEACHER TAKE NOTE

Because of the quirks in language and spelling in the letters, you may wish to read the letters aloud to younger students.

2. Instead of using the chronology, Master 4.8b, conclude by asking students to draw a timeline linking the events in these letters. Students in each group may choose to illustrate the section that they portrayed. You may want to have one copy of Master 4.8b available for reference.

For older students

Encourage high school students to read John Hickman's *The Enchanted Islands: The Galápagos Discovered* (see unit bibliography). In 17 short, highly readable chapters, Hickman fleshes out the stories summarized here and recounts many others students will enjoy.

ACTIVITY TWO

If I Could Put Time in a Bottle...

Rationale

This overview will enable students to place important events in the history of the Galápagos in the context of major events in the history of Ecuador, the United States, Canada, and the world, and to see the history of the region in terms of the vital themes and narratives of history.

Objectives

Students will:

Identify the events that have influenced the importance of the Galápagos as an environmental refuge.

Relate events in history to other events, both in time and in place.

Materials

- Student copies of Master 4.8b, Chronology of the Galápagos and Selected Events in U. S., Canadian, and World History
- Student copies of Master 4.8c, Categorizing Events
- Master 4.8d, Vital Themes in History, one copy for each small group
- Transparency made from Master 4.8d, Vital Themes in History
- Overhead projector

Procedure

A. Introduction

Distribute copies of Master 4.8b, Chronology of the Galápagos. Have students read the chart, either individually or as a class, paying particular attention to events that might have influenced the development of the islands.

B. Lesson Development

1. Distribute copies of Master 4.8c, Categorizing Events. Instruct students to decide which events belong in which categories and place the dates of the events in the appropriate spaces. (Students' answers may vary widely, and some may not be able to place all of the events.)

2. Divide the class into six groups. Assign each group one of the six topic headings from Master 4.8d, Vital Themes in History. Ask the students to share the dates they placed beside the headings on the first chart. Then have each group discuss and reach a consensus about which events belong with the heading assigned to their group. Students can underline the events on their own chronology charts that match the dates they choose.

3. Project the transparency of Master 4.8d, Vital Themes. Ask a reporter from each group to call out the dates the group

VOCABULARY

An•chor•age - a secure place suitable for ships to drop anchor.

Be•calmed - the state of a ship when it cannot sail because there is no wind.

Chro•nol•ogy - an arrangement of events in the order of their occurrence.

Des•ig•nate - to indicate and set aside for a specific purpose.

Ec•o•sys•tem - the community of plants and animals that function as an interrelated unit in nature.

El Ni•ño - a set of climatic phenomena caused by periodic reversals in the weather patterns of the eastern Pacific Ocean from cool and dry to warm and wet.

Ex•ploit - to use things or people unjustly for the benefit of a few; to put to productive use. When we speak of exploiting other persons the term is generally used in its negative sense.

Li•chen - a small complex plant that grows on another surface such as a rock or a tree.

Nav•i•ga•tor - one who sets the course, position, and distance traveled on a ship or an airplane.

Pe•nal - relating to or involving punishment.

Ren•e•gade - a person who rebels against traditional values.

Se•cede - to withdraw or separate from a state or country.

has chosen for its category. As the groups report, fill in the dates for all six themes on the transparency to make a master chart.

4. In a class discussion, ask the students:

- Why are some events listed under more than one heading? (Because events frequently relate to more than one theme.)

- Why was the first chart easier to fill out than the one the groups made? (Because the categories were more concrete and did not require as much interpretation of events.)

- The three charts represent three different ways of organizing information. What are the advantages of each? What are the disadvantages?

5. Have students return to their original groups and develop a series of questions they might wish to ask about each of the events they listed on the thematic chart, Master 4.8d. Questions might include:

- Why do you think so many nations seemed to be interested in the Galápagos in the 19th century?

- In 1813, why did the U.S. wish to destroy the British whaling fleet?

- Where can we find more information on this topic?

As time allows, students may research areas of interest and share their findings with the class.

Conclusion

Enlarge the discussion to include examples of other environmentally fragile regions in the world. Conclude with the idea that events in the world have meanings beyond when and where they happened, and should raise questions about why they happened. Try to help students see the relationship between the history of the Galápagos and the history of the rest of the world. Emphasize that the nations of the world are more interdependent than ever before, so it is more urgent now than ever that we work together to find common solutions to our problems.

Adaptations

For younger students

Teachers of young students may not want to use Master 4.8d. End the lesson after step 1 of B with a discussion of the choices students made.

For older students

1. Ask students to expand the chart by adding explanations for some of the events or adding events they'd like to see included. Challenge them to defend their choices.

2. Offer extra credit for research on one or more of the historical events listed on Master 4.8b.

MASTER
4.8 a

Letters from the Galápagos

Editor's note: *The passages that follow are all based on the observations of actual visitors to the Galápagos over a period of 465 years. The first five are taken from original documents. The last three were written for this lesson, but the events they describe are real.*

Fray Tomas de Berlanga, spiritual head of all the known and unknown Spanish territories in the Americas, was sent to Peru by the Pope to investigate conditions under the governorship of the conquistador Francisco Pizarro, especially charges that Native Americans were being treated cruelly. During eight days with no wind, enroute to Peru, crew members sighted one of the Galápagos Islands and decided to go ashore for water.

6 April 1535, Berlanga's report to Charles V, the Holy Roman Emperor

The water on the ship gave out and we were three days in reaching the island on account of the calms, during which all of us, horses as well as people, suffered great hardships. The boat once anchored, ... some were given charge of making a well. From the well there came out water saltier than that of the sea. ... With the thirst the people felt, they resorted to a leaf of some thistles like prickly pears, and because they were somewhat juicy, although not very tasty, we began to eat of them and squeeze them to draw all the water from them. [Before water was located, on the third day ashore, three men and ten horses died of thirst.]

On a second island, we saw many seals, turtles, iguanas, tortoises, and many birds like those of Spain, but so silly that they do not know how to flee, and many were caught in the hand. On the whole island, I do not think that there is a place where one might sow a bushel of corn. It is as though God had sometime showered stones; and the earth there is worthless, because it has not even the power of raising a little grass.

In the17th century, Spanish ships carrying wealth from South America were tempting prey for pirates. Pirate Captain John Cook called his ship the *Batchelor's Delight*, and his crew of buccaneers the "Merry Boys." He found the Galápagos, for all their inconveniences, ideal places to hide while waiting for a passing ship.

8 March 1684, from Cook's journal

We landed at Lobos to mend our caravel [ship] and spy for galleons. After we had been watching for about a week we sighted three tall Spanish treasure ships. Because we had the advantage of surprise, we were able to overpower them easily. We captured 100 prisoners, but when we ransacked their stores we found no gold, but only much timber, 1500 bags of flour, and eight tonnes of quince marmalade. One of the prisoners laughed in our faces and told us that his ship, the flagship of the fleet, had left Lima with 800,000 pieces of eight. When they landed at Guanchoco for water and fresh provisions, however, they heard that our caravel had been sighted, so they left the gold pieces there for safekeeping.

Then we came to anchor in a very good harbor, lying toward the northernmost end of a fine island under the equinoctial line [equator]. This was one of the islands the Spanish call enchanted islands, saying they are but shadows and no real islands. Here being great plenty of provisions, as fish, sea and land tortoises, some of which weighed at least 200 pound weight, which are excellent good food. We put in at many other islands, but we could find no good water on any of all these, save on the Duke of York's Island [later called James, San Salvador, or Santiago]. Some of the Spanish cargo we left in caves on the islands until another time that we have need.

The whaling industry dominated shipping in the 18th century. By the end of that century so many whales had been killed that they began to be scarce in the Atlantic. Great Britain's Royal Navy loaned the services of the experienced Captain James Colnett to a whaling company interested in exploring the Pacific. On one of his many voyages around the Galápagos, Colnett may have set up the post office barrel on Charles Island. To this day visiting ships check the barrel for outbound mail.

1792, Colnett's journal entry (no day or month noted)

I frequently observe the whales coming, as it were, from the main [the Caribbean] and passing along from the dawn of day until the night in one extended line, as if they were in haste to reach the Galipagoes [his spelling]. It is very much to be regretted that these isles have to this period been so little known but only to the Spaniards.

On reaching the South point of James Isle I got sight of three other islands which I had not seen before. The Southernmost, which I named Barrington Isle, is the largest and was the greatest distance from me. ... This isle appears to have been a favorite resort of the buccaneers, as we found not only seats, which had been made by them of earth and stone, but a considerable number of broken jars scattered about ... in which the Peruvian wine and liquors of that country are preserved. We also found some old daggers, nails, and other implements.

During the War of 1812, the historical setting of last year's JASON exploration, the United States was the underdog. As underdogs have always done, U.S. strategists looked for indirect ways to harass their opponent—in this case the superior, but overextended British Navy. One of the most successful of such operations was led by Captain David Porter and based in the Galápagos. With only one ship, the *Essex*, Porter managed to capture over half of Great Britain's whaling fleet. Letters intercepted from the post office barrel on Charles Island helped him to accomplish his mission.

1812, from Porter's report to his superiors

Although we knew from the letters that ships were to be expected, we waited two anxious weeks in the Galápagos before we saw the first sail. The prized [captured] ships were worth our wait, however, containing many provisions of which we stood in great need. We obtained an abundant supply of cordage [rope], canvas, paints, and tar, all of the best quality. We found on board of them also fresh meat to furnish our crew with several delicious meals. They had been in at James Island, and had supplied themselves abundantly with those extraordinary animals which properly deserve the name of elephant tortoise. The most valuable item of all we captured, however, was water, even though it was contained in the oily casks of the whale-ship, and from them derived no very agreeable taste or smell.

I would advise every vessel visiting the Galápagos to lay in good store of that necessary article, for all the fresh water in the islands owes its existence to temporary rains, and cannot be relied upon. We did however find fresh food to counteract the scurvy, both an herb resembling spinach and other fresh herbs. We found prickly pears [cactus fruit] in great abundance, stewed them with sugar, and used them to make excellent pies, tarts, etc, which helped to keep the men healthy.

In 1835 Charles Darwin spent five weeks in the Galápagos. What he saw there was to occupy his mind for the rest of his life and influence the thinking of all future generations. His first impression of the islands, however, like that of most visitors, was rather negative. When his party landed a boat on Chatham Island (San Cristóbal), the black sand burned their feet right through their shoes.

1845 or later, Darwin's *Diary* notes

The black rocks, heated by the rays of the vertical sun like a stove, give to the air a close and sultry feeling. The plants also smell unpleasantly. The whole country was like we might imagine the cultivated parts of the infernal regions [hell]. The rocks on the beach are frequented by large (2-3ft.) most disgusting clumsy lizards. They are as black as the porous rocks over which they crawl and seek their prey from the sea. Somebody calls them 'imps of darkness.' They assuredly well become the land they inhabit.

Master 4.4a Continued

William Beebe's 1924 book about the islands, *Galápagos, World's End*, was an international bestseller. The idea of living astride the equator was particularly appealing to people in cold northern climates. Many Norwegians responded to an advertising campaign mounted by the unscrupulous Harry Randall, who charged potentional emigrants large sums of money for resettlement in the Galápagos. Within two years, all but a handful of the settlers had died or gone home.

1927, from a settler's letters home

As you know, Klaus and I paid Mr. Randall a total of 6,000 kroners, our life savings. Then we borrowed from both our families and sold everything we owned to purchase cows, chickens, seeds, tools, timber, a tractor, and fishing equipment. I even sold my wedding ring to buy a drill, since Randall told us there were diamonds to be mined in the islands. After a long and dangerous journey, we landed on Charles Island. You cannot imagine the scene that met our eyes! There was nothing but hideous, bare, black rock, with grotesque animals, spiny cactuses, and a cold, soaking rain over everything.

The next day we went to work and began building houses, roads, and dams to store water. In the morning the rains came again, and washed everything away. When there is no rain, our stored water leaks out through the cracks in the rock. This is a land that makes people go insane. The only creatures that thrive are the cattle and chickens we brought, and the pigs and dogs that other families brought with them. The animals of the islands are monsters not fit to eat, though they seem not to mind our intrusion. How I long for all of you at home!

World War I had little or no impact on the Galápagos. But as World War II approached, and the importance of air power grew, the islands began to be seen as strategic. In 1938, President Franklin Roosevelt visited the islands, which had come to be known as the Achilles' heel (or weak spot) of the Panama Canal. In 1942 the U.S. Air Force built a base on Baltra, both to shield the Canal and to prevent the islands from being used as a base by the Japanese. After the U.S. abandoned the base in 1947, its materials were recycled into homes all over the islands, and the Ecuadorian Air Force established its own headquarters on the island. Most visitors to the Galápagos now arrive on Baltra and depart from there.

1942, letter written by an American nurse

Never has this island heard such noise—at least not since the last time the volcano erupted! Our engineers are using tons of dynamite to blast the lava level enough for an airstrip. For two of them, in fact. Plans call for a pair of landing strips, each 1800 meters long (about a mile). There have been some accidents, of course, but nothing worse than the loss of a few fingers. I doubt if any of the hearing loss the crew has suffered will be permanent. Our corps is also building hospitals, such as the one where I will work, roads, and a water distillation plant, so we'll no longer need to fill up our living space with bottled water. I suspect that once the work is done both crew and officers will find this service boring, but perhaps by that time the war will be over. Here, though we keep watch 24 hours a day for Japanese planes, we are so far away that we can almost forget the bloodshed.

The El Niño events of 1982-83 were an opportunity for some scientists and a setback for others, just as they were a boon to some species and a disaster for others. The rhythm of nature was thrown off course, and so was the rhythm of work at the Darwin Station. Life gradually got back to normal over the next two years, but there was little rain, so that when fires broke out in 1985 there was not enough water to put them out. The Darwin Station burned that year, along with most of its contents. Fires on Isabela Island raged from February to July.

1985, a visiting graduate student's letter to his wife

This will be short, because I'm beat. And so dirty I'm glad you can't see me! I had pictured myself in a tidy lab coat, at least part of the time, but instead I've spent the last week digging, helping to cut a firebreak 40 kilometers long (about 25 miles, that is) on Isabela Island. The animals are out of danger, but the wilderness is going up in smoke. The spring rains are still holding off, so it's up to us.

Us is a wonderfully ragtag group of Ecuadorian kids and adults, U.S. military, professional firefighters from several countries, and everybody else who can be pressed into service. At night I dream about taking a shower, but in the daytime we all sweat and strain together in the apalling heat, and there's no water to spare.

Maybe when this is all over I'm going to switch from studying iguanas to studying the plant life of these islands. I don't think anyone has appreciated it enough up until now, even though some of it is just as rare and wonderful as the animal life. Some of the scientists here are saying the same thing about the waters between and around the islands. I, for one, will never take water for granted again.

Editor's note: *In 1986 the Ecuadorian government issued a decree establishing the Galapágos Marine Resources Reserve, embracing 80,000 square kilometers (30,000 square miles) and extending 15 nautical miles beyond the outer limits of the islands. In this year's JASON Expedition, JJ and the diver Jerry Wellington will be contributing to the exploration of this new marine region.*

MASTER 4.8 b

Chronology of the Galápagos Islands and Selected Events in U.S., Canadian, and World History

***Note:** Most of the events in this chart deal with Ecuadorian history. The events listed within brackets ({ }) refer mainly to events in U.S. and Canadian history or world-wide events that would affect most countries.*

1535	Records attribute the official discovery of the islands to the Bishop of Panama, Fray Tómas de Berlanga, whose ship was becalmed by ocean currents and carried westward while on a journey from Panama to Peru. Bishop Berlanga described the giant tortoises, the iguanas, and the exceptionally tame birds.
1570	Abraham Ortelius draws the first map known to include the Galápagos Islands. The islands were labeled "*Insulae de los Galopegos*"—Islands of the Tortoises. Navigators of ocean ships often called them "*Islas Encantadas*" (Bewitched or Enchanted Islands) because of the strong, variable winds and ocean currents that made navigation through them difficult.
1600-1720	Renegades and buccaneers (pirates) use the islands as bases for raids on Spanish colonial ports in South and Central America. The islands supplied them with tortoise meat, fresh water in the rainy season, salt, and limited supplies of firewood.
1684	British buccaneer Ambrose Cowley makes the first crude navigational charts for the islands, noting anchorages where pirate ships could hide, safe from high winds and high seas.
1689-1763	{French and Indian Wars: France loses control of Canada to Great Britain.}
1774	{Quebec Act is passed, providing for preservation of French culture in Canada.}
1790	Alessandro Malaspina of Sicily, employed by the King of Spain, leads the first scientific mission to the islands. Records from this expedition have been lost.
1791	{Constitutional Act divides Lower Canada (southern Quebec) from Upper Canada (southern Ontario), and establishes limited self-government.}
1793	The English captain James Colnett investigates the possibilities for whaling in the island waters and prepares the first reasonably accurate navigational charts of the Galápagos. At about the same time, the first post office barrel is erected on Floreana (Santa Maria). Homebound whaling and fishing vessels pick up the mail and deliver it to ports nearer England and the United States.
1795-1895	More than a century of heavy exploitation endangers many island species. Whalers and sealers capture tortoises for fresh meat. One account says the whalers and sealers removed at least 15,000 tortoises from the islands between 1811 and 1844; another source estimates 100,000. Some species of tortoises were eliminated.
1807-1809	Irishman Patrick Watkins is thought to be the first human to remain in the islands for any length of time. Reports state that he was marooned on Floreana (Santa Maria), where he grew vegetables and traded them for rum from visiting whalers.
1811	{Venezuela and Paraguay declare independence from Spain.}
1813	David Porter, captain of the U.S. warship *Essex*, visits the islands. He succeeds in his mission to destroy the British whaling fleet based in the islands. He also introduces goats to Santiago Island.
1816	{Argentina declares its independence from Spain.}
1818	{Chile declares its independence from Spain.}
1819	{Colombia declares its independence from Spain and claims the provinces of Panama and Ecuador.}

1821	{Mexico, Costa Rica, El Salvador, Guatemala, Honduras, Peru, and Nicaragua declare their independence from Spain.}
1822	{Brazil declares its independence from Portugal.}
1825	Major eruption of Fernandina volcano. {Bolivia declares its independence from Spain.}
1828	{Uruguay becomes independent from the claims of Argentina and Brazil.}
1830	Ecuador secedes from the Great Republic of Colombia and becomes an independent republic.
1831	{William Lloyd Garrison founds *The Liberator* in Boston, Massachusetts. Nat Turner leads slave revolt.}
1832	Ecuador officially annexes the Galápagos and names them *Archipiélago del Ecuador*. The Ecuadorian government establishes a penal colony on Floreana. {Andrew Jackson is reelected president of the United States.}
1835	Charles Darwin visits the islands in September and October and sets the stage for a century and a half of scientific investigations. {Texas War of Independence, 1835-1836}
1836	{Martin Van Buren is elected 8th President of the United States. Arkansas enters the Union as the 25th state.}
1836-1940	Settlers make repeated attempts to colonize the islands; most fail. The Ecuadorian government sets up penal colonies. Various island natural resources are exploited—fisheries, tortoises, dyer's moss (a lichen), and salt deposits.
1837-1841	{Rebellions in the two Canadas cause Britain to reunite them.}
1850-1950	Britain and the United States make several attempts to lease or purchase the Galápagos, but the government of Ecuador resists. {Darwin's *Origin of Species* published in 1859.}
1861-1865	{U.S. Civil War}
1867	{British North America Act establishes the Dominion of Canada.}
1892	The Government of Ecuador officially designates the islands as *Archipiélago de Colón* (Archipelago of Columbus) in honor of the 400th anniversary of Christopher Columbus's (Cristóbal Colón's) first voyage to the Americas. *The Galápagos* remains the most used name.
1898	{Spanish-American War}
1914-1918	{World War I}
1931	{Statute of Westminster establishes equality of Canadian Parliament with Great Britain's.}
1934	Ecuador enacts the first protective legislation for the environment of the Galápagos.
1941-1945	World War II—United States and Canada play vital roles and emerge as major world powers. U.S. constructs air base on Baltra. Land iguanas eliminated on Baltra.
1955	The International Union for the Conservation of Nature organizes a fact-finding mission to the Galápagos.
1957	The United Nations Educational, Scientific, and Cultural Organization (UNESCO), in cooperation with the International Council for Bird Preservation, the New York Zoological Society, Time Incorporated, and the Government of Ecuador, sends an expedition to the islands to study the state of conservation and to choose a site for a research station.

Master 4.8b Continued

1959	In honor of the 100th anniversary of the publication of Charles Darwin's *The Origin of Species*, the Ecuadorian government declares all the islands, except for the areas already settled by colonists, a national park. The Charles Darwin Foundation for the Galápagos Islands is founded to ensure the conservation of unique Galápagos ecosystems and promote the necessary scientific studies.
1966	[British Guiana receives independence from Great Britain and takes the name of Guyana.]
1968	The National Park Service, under the administration of the Ecuadorian Forestry Service and the Ministry of Agriculture and Livestock, begins to carry out numerous conservation programs.
	Fernandina erupts and its caldera collapses.
1969	Organized tourism begins in the Galápagos.
1975	[Dutch Guiana receives independence from The Netherlands and takes the name of Surinam.]
1979	Member states of UNESCO declare the Galápagos Islands a World Heritage Site. This designation recognizes the Galápagos as one of the world's most significant natural areas and part of every human's natural heritage.
1982-1983	El Niño events cause major changes in population of Galápagan plants and animals.
1985	A fire set by humans burns more than 200 sq. km (77 square miles) of southern Isabela Island.

Sources

Use this listing to further explore the events in this chronology.

Dostert, Pierre E. (1986). *Latin America 1986*. Washington D.C., Harpers Ferry, WV: Stryker-Post Publications.

Hickman, John. (1985). *The Enchanted Islands: The Galápagos Discovered*. Dover, NH: Tanager Books.

Hoffman, Mark, ed. (1986). *World Almanac and Book of Facts, 1987*. New York: Pharos Books.

Jackson, M.H. (1989). *Galápagos: A Natural History Guide*. Calgary, Alberta: University of Calgary Press.

Perry, R. ed. (1984). *Key Environments: Galápagos*. Oxford: Pergamon Press.

Rachowiecki, Rob. (1989). *Ecuador and the Galápagos Islands: A Travel Survival Kit*. Hawthorne, Victoria, Australia: Lonely Planet Publications.

Categorizing Events

Spanish expeditions	
British expeditions	
United States expeditions	
Scientific expeditions	
Natural resource exploitation	
Colonization attempts	
Foreign attempts to control the region	
Environmental damage	
Environmental preservation	

MASTER
4.8 d

Vital Themes in History

Civilization, the spread of cultures, innovation	
Human interaction with the environment	
Values, beliefs, political ideas, and institutions	
Conflict and cooperation	
The impact of events or ideas occurring at the same time in different places in the world	
Patterns in the way people and their political institutions are related	

THE GALÁPAGOS

JASON CURRICULUM

UNIT FIVE

FOLLOW-UP

BACKGROUND
Follow-Up

Students will look backward and forward in this concluding unit of the curriculum. Now that they have participated in the Galápagos expedition via telepresence, the lessons in Unit Five will offer them several routes for ongoing involvement. They will tie up loose ends from the classroom work that preceded their visit to the downlink site, and review that work in light of the actual expedition. Students will share their reactions to their experience, and discuss any questions that remain unanswered.

The activities in the final unit will be more successful if students have maintained JASON journals and kept them up to date. Encourage students to follow up on their individual interests and continue to add to their journals, seeking out answers to unanswered questions, learning more about science-and-technology related careers, continuing to enroll in science and social studies classes, and keeping up with new developments in technology.

The Follow-Up unit offers two culminating activities. In the first, students enact an international conference on the future of the Galápagos Islands. They will learn about the wide range of careers involved in making decisions for the Galápagos, and the broad-based international cooperation that has been necessary to preserve the islands. Participating students will gain a sense of responsibility for the environment not only of the Galápagos, but of the world as well. In the second activity, students prepare a museum exhibit to share what they have learned. This activity also emphasizes careers, but focuses on those that contribute to presenting scientific exploration in a museum setting. Students will take the roles of museum personnel planning and executing an exhibit about the Galápagos JASON Project. Activities may include research, design, construction, and public relations.

Most teachers will not have time to do every activity in this curriculum before their class visits the downlink site. However, many of the lessons are not dependent solely on the JASON Project, but may be used throughout the year to enrich many topics in the science and social studies curricula.

DEBRIEFING AND DISCUSSION

5.1

Rationale

Students will benefit most from their telepresence experience if they spend some time soon afterwards relating what they have seen to their preparation and problem-solving activities. Then students can expand their involvement by collecting information on global conservation issues and by writing letters to scientists, government agencies, and legislators.

Objectives

Students will:

Discuss their reactions to the downlink experience and to the JASON Project.

Review the questions in their JASON journals to see if they were answered and how the answers compared with their expectations.

Organize and share data from their journals by completing a checklist.

Plan ways to continue their involvement with scientific exploration and environmental preservation, such as reading, participating in other science programs, and corresponding with JASON Project participants.

JASON
JOURNAL

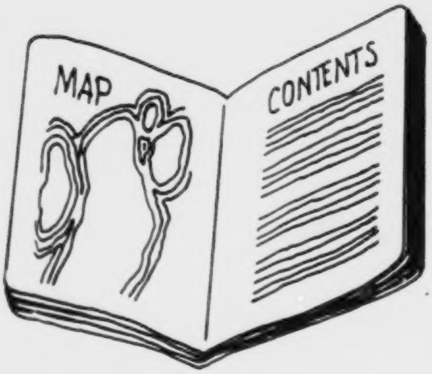
Materials

- JASON journals
- Chalkboard
- Chalk
- Pens and other writing materials
- Reference materials (See unit bibliography.)
- Student copies of Master 1.2f, Expedition Checklist
- Transparencies made from Master 1.2f, Expedition Checklist
- Overhead projector
- Student copies of Master 5.1a, Careers Puzzle (*optional*, for younger students adaptation)
- Back of Master 5.1a, Answer Key

Procedure

Teacher Preparation

Just before the visit to the downlink site, review the checklist (Master 1.2f) that students received in Unit 1. Instruct the students to check off everything they observe, either during or immediately after the JASON Project transmission, and bring the lists to class in their JASON journals.



A. Introduction

Encourage students to discuss and compare their impressions of the museum experience. As they talk, make a chalkboard list of what they liked most and what they liked least. Ask why certain aspects of the experience were more interesting than others. Ask what expectations were met, and if any were disappointed. Other possible questions: What did you find most surprising? What part will you remember the longest? What would you have done differently if you had designed the expedition?

B. Lesson Development

1. Project the transparency made from Master 1.2f so students can combine the individual lists in their journals. As a class, build one comprehensive log of the organisms students saw in the broadcasts. You may also want to make lists of the equipment they observed being used and the careers that were represented.

2. Ask students to review their journals, noting the questions they had at the end of each lesson. Ask if the questions have been answered. Allow time for students to write the answers that they have not already entered and highlight any still-unanswered questions. Discuss the questions students still have so they can try to answer them in their journals.

3. Refer back to the role-playing activity in Unit 1, Lesson 3. Ask students if they would take the same stand now that they took then, before completing the project. Encourage discussion of the issues in light of the new knowledge gained.

4. Compose one class letter to the site coordinator expressing appreciation and summarizing student reactions to the telecast. If your downlink site was a museum, students interested in museum careers might send separate letters with questions or requests for information.

5. Ask students to identify one major interest, concern, or question relating to the JASON Project in the Galápagos. Help them to focus their questions and decide where to write and to whom. Students who have a specific career interest can ask their school's career counselors for addresses and more information. Students with a particular conservation concern can get more information by writing to their legislators. The offices of state and U.S. senators and representatives can supply information about what bills are pending and what committees or subcommittees are addressing issues in the area of the student's interest.

6. Students with questions still unanswered may find

TEACHER TAKE NOTE

Most school libraries have the useful Department of Labor publication *Dictionary of Occupational Titles*.

information in current periodicals from the library. (See bibliography for some appropriate journals.) For information dealing specifically with the JASON Project they can write to:

Mr. Tim Armour
JASON Foundation for Education
PO Box 733
Woods Hole, MA 02453

The Charles Darwin Foundation for the Galápagos Isles
Estacion Darwin
Isla Santa Cruz
Galápagos, Ecuador

JASON Foundation For Education
391 Totten Pond Road
Waltham, MA 02154

C. Conclusion

Encourage students to plan follow-up and extension projects. Here are some possible assignments:

- Begin a new journal. Collect and record information about the area in which you live. Keep a naturalist's journal on your yard, the schoolyard, or a nearby park. Take your journal if you go on a trip, and record your observations. Watch for geological landmarks and for interesting organisms.

- Read about and collect information about some other place in the world you would like to visit.

- Keep track of conservation issues. Follow the news; watch for magazine articles, TV shows, and museum exhibits on the topic.

- Find out what species are on the endangered list for the U.S. and/or your state. Choose one organism and learn more about it. Collect information and make suggestions for the preservation of this organism.

Adaptations

For younger students

1. Students might enjoy putting together a book on their Galápagos telepresence experience. Each child could contribute one picture, story, or poem; or children could work as a class or in groups to produce their book.

2. Distribute copies of Master 5.1a, Careers Puzzle. Answers are on the back of the master.

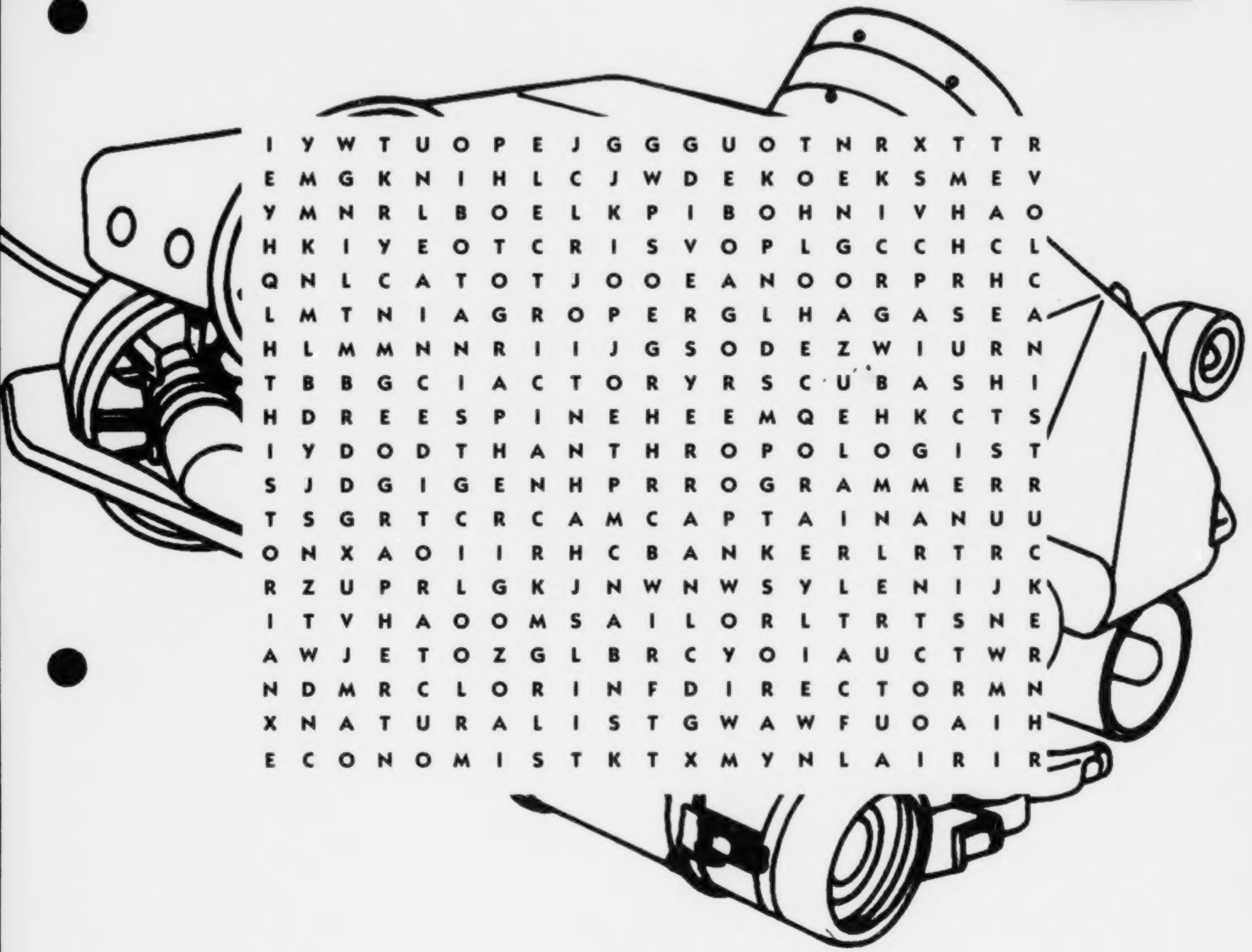
For older students

1. Encourage interested students to do further research and to compile a status report on the Galápagos Islands as a natural heritage park. They might investigate current issues facing the Charles Darwin Foundation and the Darwin Research Station.

2. Spanish speaking students might agree to translate a class letter to the Ecuadorian Ministry of Agriculture expressing appreciation for Ecuador's leadership in preserving the world laboratory that is the Galápagos Islands.

JASON
PROJECT

Careers Puzzle



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E	C	O	N	O	M	I	S	T	K	T	X	M	Y	N	L	A	I	R	I	R

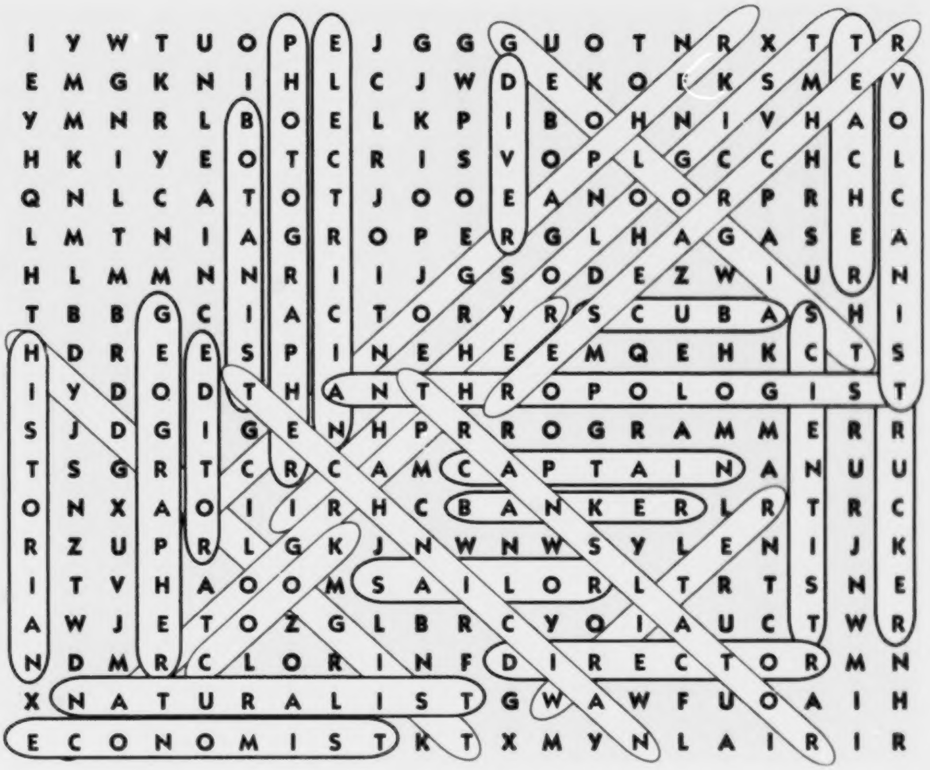
Can you find these words?

ANTHROPOLOGIST
PHOTOGRAPHER
HYDROLOGIST
NATURALIST
GEOGRAPHER
SCIENTIST
VOLCANIST
TRUCKER
SAILOR
SCUBA

ICHTHYOLOGIST
CARTOGRAPHER
TRANSLATOR
HISTORIAN
CAPTAIN
DIRECTOR
TEACHER
BANKER
DIVER
OCEANOGRAPHER

ELECTRICIAN
RESEARCHER
TECHNICIAN
ECONOMIST
GEOLOGIST
BOTANIST
WRITER
EDITOR
COOK

Back of Master 5.1a
Answer Key



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Sharing What We Know

5.2

ACTIVITY ONE

Inventing the Future
A Simulation

Rationale

The JASON Project exploration in the Galápagos is a collaborative effort involving hundreds of people with an extraordinary variety of job skills in many career areas.

Objectives

Students will:

Research careers related to the JASON Project exploration.

Role-play a specific career in a conference designed to examine options for the future of the Galápagos.

Propose and evaluate alternative futures for the Galápagos.

Materials

- Master 5.2a, JASON Career Name Tags (four sides)
- Pins for fastening tags
- Container to hold name tags for drawing (*optional*)
- Master 5.2b, Role Cards
- Career reference materials
- Paper and pencils or pens
- Glue
- Student copies of Master 1.2g, The JASON Project Consortium (Students may already have these in their journals.)
- Felt marker (*optional*, for younger students adaptation)
- Small index cards (*optional*)
- Large ball of yarn (*optional*)

Procedure

Teacher Preparation

Before class, copy Master 5.2a, JASON Career Name Tags, and glue the page onto construction paper or other heavy paper. Cut the tags apart. Decide how many tags you will need for your class and make a selection, but be sure to use all of the first group and at least one from each of the other five groups. Also copy and cut apart the role cards on Master 5.2b. You may need to make more than one copy of some of the role cards.

A. Introduction

Explain: The Darwin Foundation, whose Secretariat for the Americas is headquartered at the Smithsonian Institution in Washington, D.C., is an international body created to support research activities in the Galápagos and to promote the conservation of the archipelago's plants and animals. To accomplish this purpose, the foundation operates the Charles Darwin Research Station (CDRS) at Puerto Arroya on Santa Cruz. Since its founding in 1958, the foundation

VOCABULARY

Ar•chi•pel•a•go - a group of islands sharing common physical and locational characteristics.

El Niño - a set of events caused by periodic reversals in the weather patterns of the eastern Pacific Ocean from cool and dry to warm and wet.

UNESCO - the United Nations Educational, Scientific and Cultural Organization.

TEACHER TAKE NOTE

Two alternative culminating activities are offered in this lesson. Each will take considerable time and effort. Read them both and choose the one that seems most appropriate for your class.

TEACHER TAKE NOTE

If possible, allow two full class periods for this activity.

TEACHER TAKE NOTE

See Master 1.2e, in Unit 1, for more information about the Darwin Station and its work.

has spent millions of dollars from small and large donors worldwide to aid hundreds of scientists in their on-site research. The foundation has also served as a consultant to the Ecuadorian Government on a broad range of topics affecting the islands. Both the foundation and the Darwin Station have worked with Dr. Ballard and his team through all the stages of this year's JASON Project exploration.

B. Lesson Development

1. Present your students with this hypothetical situation: Because of the excitement generated by the coming of the JASON expedition to the Galápagos, the Darwin Foundation is calling a conference to develop recommendations for the future of the islands. The people attending the conference—all of whom were involved directly or indirectly with the JASON Project—will evaluate the various proposals and rank them in order of desirability and practicality. After the conference the proposals will be presented to the Ecuadorian Government for its consideration.

2. Using the JASON career name tags, either assign each student a career or allow each to select one at random from a box. You will probably not need all the cards, but try to maintain a balance among the various groups.

TEACHER TAKE NOTE

Because the Director of the Darwin Foundation is essential in assuring the success of the simulation, it is important to assign a particularly capable student to this role. The director not only convenes the conference, but also monitors the break-out groups and chairs the planning session.

3. Allow time for students to use the reference materials to research their assigned careers. At the end of this period ask each student to write a brief job description which answers these questions:

- What is the nature of the job?
- What kind of training and education does the job require?
- Does the job relate to the JASON Project expedition in the Galápagos?

When the research is completed, have each student share his or her assigned job description with the class and tell how the job relates to the overall mission of the JASON Project in the Galápagos.

4. Next, set the stage for the conference. Distribute the role cards from Master 5.2b and ask students to read the information on the cards. Tell them that during the conference they must represent the interests and point of view of their career as it relates to the future of the Galápagos. Divide the class into five groups: (1) Visiting Scientists, (2) Darwin Foundation Scientists, (3) Technicians, (4) Residents of the Galápagos, and (5) International Community. The challenge to each group is to develop a set of recommendations to be presented, by a spokesperson for the group, at the conference planning session. The recommendation must be arrived at through consensus. The group should be prepared to explain, justify, and defend what it decides. Proposals must be both realistic and serious.

5. Now have the student playing the role of the Darwin Foundation Director open the session. To begin, each group must present its proposals for discussion and debate. The mission of the session is to agree to a set of proposals for the Ecuadorian government that will guide the future development of the Galápagos. These proposals need not be extensive, but they should reflect the best thinking of the conference members as they represent their career roles.

C. Conclusion

Once the conference participants have agreed on a common set of recommendations and the conference has been adjourned, hold a debriefing session so that students can discuss the difficulties they faced in representing their career positions at the conference. Conclude by challenging the class to prepare a letter with their recommendations and send it to:

Executive Director
Secretariat for the Americas
The Darwin Foundation
The Smithsonian Institution
Washington, DC 20560

Students may also want to write to some of the other organizations listed on Master 1.2e, The JASON Project Consortium.

TEACHER TAKE NOTE

Students who have done all the activities in Unit 1 and a good sampling of those in the other units should be familiar with the specific issues facing their group. If yours need additional preparation, brief yourself by reading Lesson 2 in Unit 1, Activity Two of Lesson 7 in Unit 3, and Lesson 4 in Unit 4.

Adaptation

For younger students

Try this webbing activity instead:

1. As a class, brainstorm a list of jobs related to the JASON Project. You may use the list on Master 5.2a as a starting point, but be sure to delete some careers that would be hard for students to understand and substitute some that are more concrete, such as cook and forklift operator. Write the job titles on index cards, one per card. The total number of cards should equal the number of students in the class.

2. After the list is completed, hold up one card at a time and ask the students to explain how the job could be related to the JASON Project. Example: Forklift operator will pick up the JASON equipment and place it on the ship.

3. Give one card to each student. As a student receives a card, he or she will briefly describe that career to the class. (Be prepared to help out as necessary.) Continue until each student has a card.

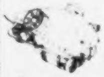
4. Have the students move from their desks and get into a big circle, taking their cards with them. The students must hold their cards so they can be seen at all times.

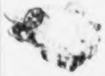
5. Give the ball of yarn to one student and ask that student to call out the title of another worker within the group who he or she may need to do the job assigned. (Example: The computer programmer may need a computer technician to repair the computer when it malfunctions.) At this time, the computer programmer holds onto the end of the yarn, but rolls the ball to the computer technician. The computer technician may need an electrical engineer to fix the electrical wiring in the van. The computer technician holds onto the yarn, but rolls the rest of the ball to the electrical engineer. Continue until every student is holding onto one part of the yarn. By the time all the students have stated their needs for the services other careers offer, the center of the circle will be a dense yarn web.

6. Give students a few moments to see and feel the complexity of their interdependence in these assumed roles. When all are back in their seats, discuss the importance of everyone working together to make the JASON Project a success.

TEACHER TAKE NOTE

If possible, reserve the playground or the gym for this activity.


Jason Jr. 2
Geomorphologist


Jason Jr. 2
Geologist

ACTIVITY TWO

Seeing is Believing

Rationale

Scientific study is of little value unless the results are communicated. Sometimes researchers will publish their experiences and findings in books or articles. Other times, research findings will be presented in a television show or in a video. Museum exhibits are also excellent vehicles for presenting a range of information to the public.

Like scientists working together on an expedition, museum staff of differing backgrounds and interests work together to develop an exhibit. Museum staff research, interpret, and design exhibits that compile research information and present it visually to the public.

Objectives

Students will:

Plan a museum exhibit that interprets their experience in the JASON Project.

Work together to construct an exhibit for public viewing.

Play the roles of various museum staff members, including curators, carpenters, researchers, interpreters, designers, and public relations personnel.

Materials

- Student copies of Master 5.2c, Museum Workers and their Responsibilities
- Reference books for learning more about careers (See unit bibliography.)
- Construction materials (cardboard, papier mâché, and others) as needed to complete the exhibit

Procedure

A. Introduction

Discuss why it is important to present scientific research in a way that can be understood by the public. Science and applied science (technology) shape our present and are shaping our future. Citizens must understand the issues in order to participate in making decisions. Explain that museums are an important part of our educational system, although their role is sometimes overlooked. In this activity, students will play the roles of museum employees who have been involved in presenting the JASON Project and want to make it available to more people in their community.

B. Lesson Development

1. Ask students how many jobs they can think of that need to be done to develop and maintain a museum exhibit. Make a list on the chalkboard, then distribute copies of Master 5.2c. Go over the list in class, or give students time to read the information on their own. Compare the list provided with the class list, and discuss the many tasks involved in museum work.

2. Help students decide as a class what type of exhibit they want to develop to share their experience with others. For example, do they want to feature one part of the Galápagos

expedition, or highlight as many parts as possible? How large do they want their exhibit to be? How large an exhibit is practical, given all the limitations of time, space, and material? When and where will the exhibit be shown?

3. Have each student select a job from the list on Master 5.2c. Make sure that the jobs chosen are distributed fairly evenly among the six divisions. Select one student from each division to act as leader.

4. Call a meeting of just the leaders to discuss the role of each division in planning and developing the exhibit. Meanwhile, the other students can consult reference books to learn more about their individual specialties and take notes that may be useful.

5. Ask leaders to meet with their divisions and assign tasks to each member. From their group lists, make a master list of assignments and distribute it to the class so that everyone knows what the other students are doing.

6. Have the students complete their tasks. (This will probably take some time outside of class.) Suggest that they meet or talk with members of other divisions as they are working so they can solve any problems that arise. Students should report to their division leaders as soon as their jobs are completed.

7. While the exhibit is being assembled, have division leaders meet to make final decisions for the exhibit. Be available to help, but leave as much initiative as possible in student hands.

C. Conclusion

Once the exhibit is complete, discuss what problems were encountered and how they were resolved. Invite other students or parents in to see your exhibit.

Adaptations

For younger students

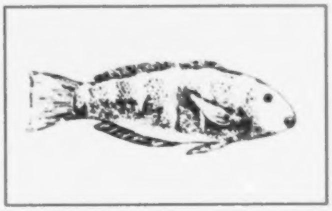
With younger students the teacher may need to take more responsibility for planning and designing the exhibit and assigning duties to each student.

For older students

Either before or after they do this activity, assign students to visit a local museum and study one of the exhibits. If they go after constructing their own exhibit, they can critique the museum exhibit and discuss how each museum division may have been involved in developing it.

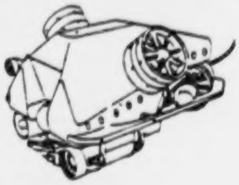
TEACHER TAKE NOTE

Allow at least two full class periods for this activity. If your schedule does not allow time for students to actually construct an exhibit, limit them to making sketches of the proposed exhibit, lists of tasks and the skills needed to do them, and perhaps a model or small-scale version.



JASON Career Name Tags

MASTER
5.2a



Jason
Jr.
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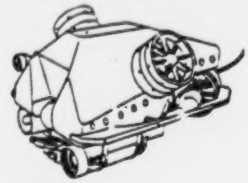
____
Meteorologist (U.S.)



Jason
Jr.
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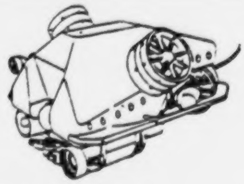
Anthropologist (U.K.)



Jason
Jr.
1

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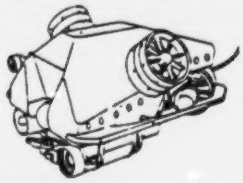
Volcanologist (Iceland)



Jason
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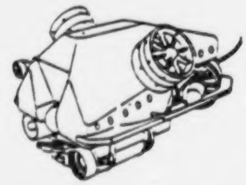
Geologist (U.S.)



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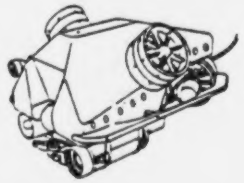

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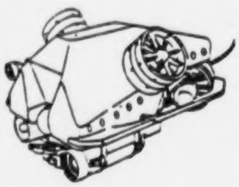
Hydrologist (U.S.)



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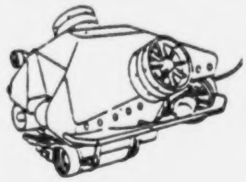
Oceanographer (CDRS)



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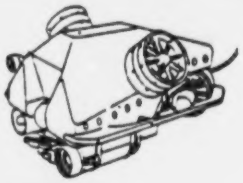

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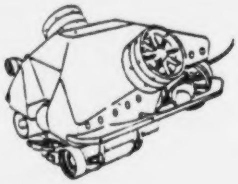
Terrestrial Biologist (CDRS)



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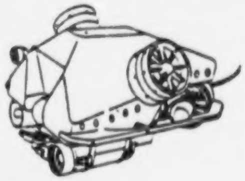
Botanist (CDRS)



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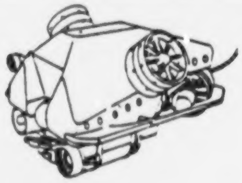
Ornithologist (CDRS)



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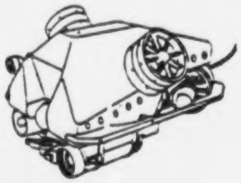
Geomorphologist (CDRS)



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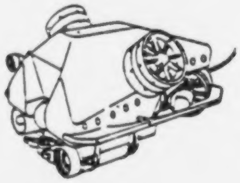
Forklift Operator
(JASON Project)



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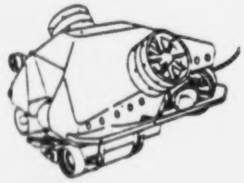
Computer Technician
(JASON Project)



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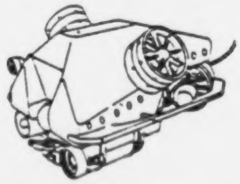
TV Camera Technician
(JASON Project)



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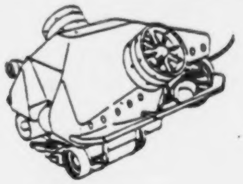
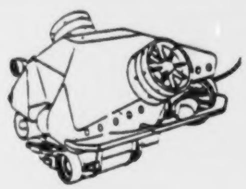
Electrical Engineer
(JASON Project)



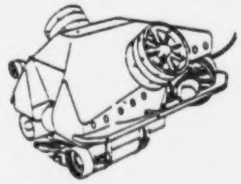
Jason Jr. 3 ____________________

Film Editor
(JASON Project)



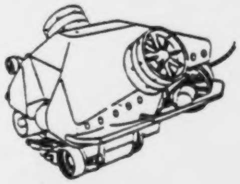
Jason Jr. 4 ____________________

Director of the
Darwin Foundation



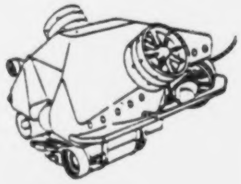
Jason Jr. 4 ____________________

Mayor of Puerto Arroyo



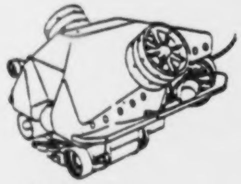
Jason Jr. 4 ____________________

Ecuadorian Director
of Tourism



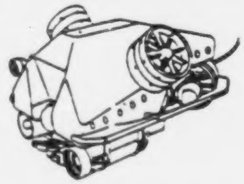
Jason Jr. 4 ____________________

Galápagos National Park
Service Warden



Jason Jr. 4 ____________________

Cook
(Resident of the Galápagos)



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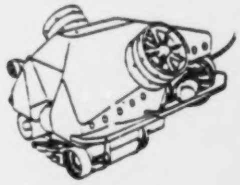
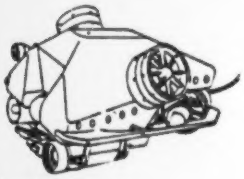
Translator
(Resident of the Galápagos)



Jason Jr. 4 ____________________

Nature Photographer
(Resident of the Galápagos)



Jason
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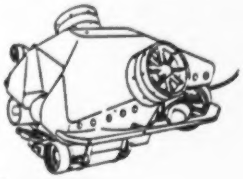
Ecuadorian Teacher
(Resident of the Galápagos)



Jason
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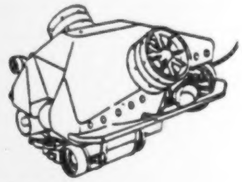
Computer Programmer
(Resident of the Galápagos)



Jason
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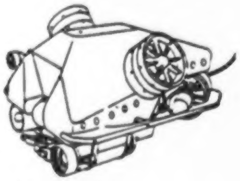
UNESCO Representative



Jason
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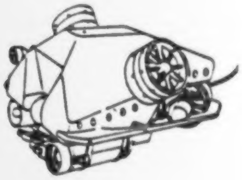
Geographer (Brazil)



Jason
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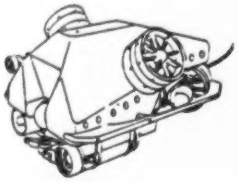
Cartographer (Ireland)



Jason
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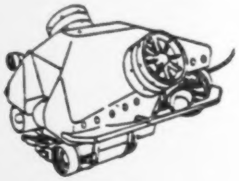
Economist (Ecuador)



Jason
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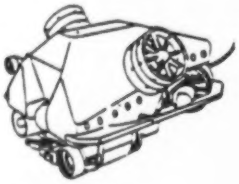
Maritime Historian (U.K.)



Jason
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Science Historian (U.S.)

Role Cards

MASTER
5.2b

4. Mayor of Puerto Arroyo

Your job is to take an impartial view of the information that you are presented. You must represent the views of your constituents, but you know that the funding Ecuador gets from international agencies and the scientific research that goes on in the Galápagos is an important source of income for the country. The National Park and the Darwin Research Station will be out of business if the resources are destroyed, and your government has given these groups leadership in management of the Galápagos, so their opinions should be seriously considered.

4. Ecuadorian Director of Tourism

Organized tourism in the Galápagos began in the mid-1960s. It now employs more people than the traditional farming and fishing of the islands. In 1970, there were about 4,500 visitors. This has grown to a present total of over 26,000 per year, even though there is an official limit of 25,000. Tourism is good for the islands and their resources, and you are willing to work together with other interested parties to see that the islands' resources are preserved without discouraging tourists.

5. UNESCO Representative

The UN Educational, Scientific and Cultural Organization (UNESCO) created the Darwin Foundation and established the Galápagos as a Biosphere Reserve. In general, the UN viewpoint on resources is one of protection. Given all the negative aspects of tourism, you think Ecuador should consider barring all tourists from the islands, preserving the area for research the way Antarctica is preserved. UNESCO conducts its own educational programs; they, of course would be allowed.

4. Galápagos National Park Service Warden

Your work is recognized internationally in both educational programs and resource management. You seem to be doing things right, and you feel that continuing the present practices on the islands would be wise. You will continue to monitor tourist impacts and will recommend restrictions in the future if necessary. At the present time you are convinced that the more people know about the islands, the more they will be determined to protect them. Your staff is well trained in reaching audiences with information on protecting the environment, including advance materials for cruise boats to offer passenger education and prevent marine pollution.

1. Visiting Scientists

You are very concerned about the possible damage to the environment of the Galápagos from tourists. Imagine what would happen to research if startled tourists stomped on Sally Lightfoot crabs or crushed bird eggs as they scrambled across the rocky beaches and calderas. Since television does a great job of teaching people about the Galápagos, you feel that is enough of an education to make people feel good about protecting this environment. They don't have to jeopardize it by coming in person. You would, however, like to see groups of science teachers and scientists-in-training come here to study the ecosystem. The world needs more scientists, not more tourists.

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2. Darwin Foundation Scientists

Research is extremely important because we need to understand the unique systems of the islands in order to use them wisely and protect them from human abuse. The Research Station you operate has been active in re-establishing the giant tortoise population on Pinzon, for example, by raising the young tortoises to a size that the introduced rats can't eat. The station keeps track of vegetation changes caused by introduced herbivores, and has had programs for getting rid of wild dogs. Many of the Galápagos' problems are the result of public ignorance. You have mixed feelings on the value of tourism.

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3. JASON Project Technicians

Participating in this expedition has been challenging and rewarding. You have enjoyed helping to bring the wonders of the Galápagos to people who would otherwise only have read about them in books. But the rough terrain presented enormous obstacles to going where you wanted to go and using your equipment as it was meant to be used. If you ever work here again, you'd like to see more roads and paved areas to make it easier to do your task.

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4. Residents of the Islands

You have seen many new hotels and boat lines develop to accommodate the tourist trade, and you want even more to take advantage of this new source of income. Almost one-fifth of Ecuador's income is from tourism. People who used to be poor farmers on the lava soils, or who fished in small boats for their family's dinner, now can make a dependable living and have a few extras as well. None of your animals are threatened by the tourists, and you feel that your tour guides do a great job of teaching the tourists to treat the islands with care. El Niño hit tourism hard in 1982-3, with many animals dying or disappearing from tourist view. You have a lot of lost income to make up.

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5. Members of the International Community

You very much admire the job that has been done so far in balancing various interests for the good of all the world. You feel that the Galápagos belongs to the world, and would like to see the islands remain accessible. You have friends and family who have never visited this wonderful place where you have the opportunity to work, and you hope that possibility will be there for them. At the same time, you are aware of the need for careful planning.

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Museum Workers and their Responsibilities

MASTER
5.2c

If you worked at a museum, you might have one of these jobs and some of these responsibilities. Can you think of other experts you would need to help you develop an exhibit on the Galápagos expedition?

Curators

Responsibilities: To collect and preserve objects.

Specialties:

- natural science
  - –zoologist
  - –geologist
  - –botanist
- history
  - –anthropologist
  - –conservator of objects
- technology
  - –oceanographer
  - –librarian

Researchers

Responsibilities: To gather information about the objects in the museum's collection; often publish books and articles about their work.

Specialties:

- marine biologist
- climatologist
- zoologist
- marine botanist
- ecologist
- geologist
- ocean biologist
- physical oceanographer
- botanist
- computer specialist
- historian
- geophysicist
- robotics engineer
- herpetologist (specialist in reptiles)
- ichthyologist (specialist in fish)
- ornithologist (specialist in birds)

Interpreters

Responsibilities: To design and carry out programs and activities to help the public better understand the exhibits and the museum.

Specialties:

- exhibit guides
- educators (teachers)
- volunteers
- writers
- program moderators
- floor supervisors
- public programs specialists
- editors

Exhibit Designers

Responsibilities: To organize the objects or information and present it all in a way that will interest the public.

Specialties:

- designers
- illustrators
- preparators
- photographers
- carpenters
- audiovisual specialists

Communication Experts

Responsibilities: To publicize the work of the museum and raise money to fund its many projects.

Specialties:

- fund raisers
- editors
- graphic designers
- grant writers
- writers
- illustrators

Merchandising Staff

Responsibilities: To purchase items that relate to the exhibit and resell them at the museum store.

Specialties:

- purchasing agent
- store manager
- cashier
- bookkeeper
- advertising manager
- catalog editor

CURRICULUM RESOURCES

Unit 1. Introduction

Books

Ballard, R.D. (1983). *Exploring our living planet*. Washington, DC: National Geographic Society.

Ballard, R.D. (1987). *The discovery of the* Titanic. New York: Warner.

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Ballard, R.D. (December 1985). "How we found the *Titanic*." *National Geographic*, 168 (6): 696-719.

DeWall, Marily. (March 1989). "Exploring the Mediterranean with JASON." *Science Scope*, 12 (6): 24-27.

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Grosvenor, G.M. (August 1990). "Hands-on high technology." *National Geographic*, 178 (2): President's page.

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Unit 2. Technology

Books

Ballard, R.D. (1988). *Exploring the* Titanic. Toronto: Madison Publishing, Inc.

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Carter Associates. (1985). *Career choices for students of mathematics*. New York: Walker.

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Reed, Maxine K., & Robert M. Reed. (1986). *Career opportunities in television, cable, and video*, 2nd ed. New York: Facts on File.

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Periodicals

Ballard, R.D. (August 1976). "Window on Earth's interior." *National Geographic*, 150 (2): 228-249.

Ballard, R.D. (April 1985). "NR-1, the Navy's inner-space shuttle." *National Geographic*, 167 (4): 450-459.

Ballard, R.D. (December 1985). "How we found the *Titanic*." *National Geographic*, 168 (6): 698-705.

Videos

The robotic revolution. Washington, DC: National Geographic Society. No. 51193. (24 minutes).

Secrets of the Titanic. Washington, DC: National Geographic Society. No. 51287. (55 minutes).

UNIT 3. Science

Books

Beakley, George C. (1984). *Careers in engineering and technology*, 3rd ed. New York: Macmillan.

Beason, Christopher. (1974). *Careers in conservation*. Minneapolis: Lerner Publications Co.

Black, Juan. (1973). *Galápagos, Archipielago del Ecuador*. Spanish. Quito, Ecuador: Charles Darwin Foundation and World Wildlife Fund.

Bowman, R.I., ed. (1966). *The Galápagos*. Berkeley: University of California Press.

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JASON CURRICULUM

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CURRICULUM GLOSSARY

Absolute location - a point on a map or globe expressed as the intersection of lines of latitude and longitude.

Acceleration - the rate at which an object speeds up.

Adapt - of a species, to gradually develop changes in response to changing circumstances.

Adaptation - gradual change in response to environmental conditions.

Algae - a group of marine plants that includes seaweeds and tiny floating plants called *phytoplankton*. (**Algae** is plural; **alga** is the singular form.)

Algal bloom (also called **plankton bloom**) - an unusually high concentration of tiny floating algae, or phytoplankton. In the Galápagos, algal bloom occurs within a few days of an upwelling that brings cold, nutrient-rich waters to the surface.

Alternative - a choice; something that can be chosen instead of something else.

Altimeter - a barometer used to measure altitudes and to find distance above sea level.

Analemma - a graduated scale, shaped like the figure eight, usually found on sundials and globes.

Anchorage - a secure place suitable for ships to drop anchor.

Archipelago - a group of islands sharing common physical and locational characteristics.

Basalt - the dark, dense rock forced out during a lava flow.

Bathymetric - having to do with the measurement of large bodies of water. A bathymetric map is one that shows how deep water is at various points.

Becalmed - of a ship, unable to sail because there is no wind.

Benthic organisms - plants and animals that live permanently in or on the ocean bottom.

Botany - the biological science that studies plants or the flora (plant life) of a particular region or district.

Buoyancy - a force that acts upon an object causing it to float.

Caldera - a steep-walled, flat-floored depression at the top of a volcano.

Camouflage - a natural or artificial patchwork coloration that makes something blend in with its surroundings.

Carnivores - animals that eat other animals.

Chronology - an arrangement of events in the order of their occurrence; the science that deals with time by regular divisions and that assigns dates to events.

Cinder lava - sharp, rough, or loose lava.

Coastal ocean - shallow ocean water less than 200 meters deep

Coaxial cable - a tube of electricity-conducting material surrounding a central conductor that is held in place by insulators, and used to transmit high frequency signals.

Commensalism - a relationship in which two or more organisms live in close association, and one may derive some benefit, but neither harms nor is parasitic on the other.

Competition - rivalry between organisms for food, shelter, or control of a territory. Competition occurs both within the same species and among different species.

Conservation - a wise and responsible use of resources.

Consumers - organisms that cannot produce their own food, but must feed on producers or animal matter.

Coordinates - the latitude and longitude numbers that express (in degrees north or south and east or west) location as a point on a map or globe.

Countercurrent - a current that flows in the opposite direction from a major current.

Crater - a funnel-shaped depression at the top of a volcano marking the vent through which volcanic products are ejected.

Current - the part of a fluid body moving continuously in a single direction.

Density - the amount of mass an object has per unit of volume.

Designate - to indicate and set aside for a specific purpose.

Dispersal - the process by which organisms are spread from one place to another.

Disturbance - a change that affects or disrupts the normal order of movement.

Dorsal - belonging to the top side.

Downlink - the transmission signal from a communications satellite which is received by a station on Earth.

Ecosystem - a community of plants and animals that function as an interrelated unit in nature.

El Niño - a set of phenomena caused by dramatic changes in the weather patterns of the eastern Pacific Ocean from cool and dry to warm and wet.

Elevation - in maps, the altitude above sea level. Elevation provides a more objective measurement than height, which is altitude above the surrounding area.

Endemic species - a class of animals or plants that is native to a region, not introduced or merely resident.

Epiphytes - plants that grow upon other plants but do not receive food, water, or minerals from them. Epiphytes receive their nourishment from the atmosphere.

Eradication - doing away with, or removal.

Escape velocity - the speed an object must attain to escape from the Earth's gravitational force.

Exploit - to use things or people unjustly for the benefit of a few; to put to productive use. When we speak of exploiting resources or other people, the term is generally used in its negative sense.

False color - the use of assigned (not natural) colors to provide new information about an object of study.

False color map - a map that uses colors to represent differences other than color.

Fathom - a unit of water depth equivalent to 1.85 meters or 6 feet.

Feedhorn - the section of a satellite receiver at which a concentrated signal is focused by the parabolic dish.

Feral - of animals, wild, as opposed to domestic or tame.

Fiber optic cable - a bundle of hair-thin, flexible, transparent rods through which light is transmitted. Other forms of energy can be converted into light energy to be transmitted by fiber optic cable.

Filter feeders - aquatic organisms that obtain their food by straining smaller organisms or bits of food from the water.

Footprint (satellite) - elliptical area on the surface of the Earth within reception range of a satellite.

Garúa (Spanish) - light rain or drizzle.

Geology - the systematic study of the origin, history, and structure of the Earth; the structure of a specific region of the Earth's surface.

Geosynchronous - moving at the same speed as the Earth's rotation, so that it appears to be standing still.

Germination - the development of a sprout or young plant from a seed that has been moistened.

Gravity - the attractive force between the Earth's mass and the mass of objects at or near the surface of the Earth.

Habitat - the environmental conditions in which an organism lives.

Herbivores (also called **grazers**) - animals that eat producers; these animals are in the second trophic level.

Hip chain - instrument used to measure distance and worn around the hips to free the hands.

Hot spot - a volcanically active area on the Earth's surface where a crustal plate rides over a rising plume of hot material from the mantle.

Hydrographic - related to the systematic study of physical conditions, boundaries, flow and related characteristics of surface waters, such as oceans, lakes, and rivers.

Index fossil - a fossil that, because its approximate date is known, allows scientists to determine the age of the rock in which it is imbedded.

Inertia - the property of matter that causes it to remain at rest, or if in motion, to remain in continuous motion in a straight line unless acted upon by an outside force (Newton's first law of motion).

Interdependence - a relationship in which organisms meet each other's needs.

Introduced species - a class of animals or plants that is not native to a region, but has been brought in from outside and allowed to propagate.

Island - a tract of land completely surrounded by water.

Isotherm - a line connecting areas of equal temperature.

Knot - a measure of speed equivalent to one nautical mile (usually 1852 meters) per hour.

Laser - a device for producing a narrow, coherent beam of light of a single color.

Latitude - the angular distance (in degrees) around the globe north and south of the equator.

Lava tubes - caves or tunnels formed when air is trapped during a volcanic explosion.

Lichen - a small complex plant that grows on another surface such as a rock or a tree.

Logo - a graphic or symbol that identifies a specific product or organization.

Longitude - the angular distance (in degrees) around the globe east and west of the prime meridian.

Magma - molten rock material within the Earth. When magma erupts to the surface it is called **lava.**

Maneuverability - ease with which an object can change positions.

Mass - the quantity of matter present in an object or substance.

Minute - one-sixtieth of the distance between two lines of latitude or longitude.

Momentum - the property of a body in motion that causes it to continue in motion unless interrupted.

Mutualism - a relationship between two organisms in which both receive some benefit. (**Mutualistic** is the adjective form.)

Myth - a traditional story, usually of unknown origin, that embodies beliefs of particular significance to a culture.

Naturalist - a person who studies natural objects and organisms along with their evolution, origins, description, and interrelationships.

Navigator - one who sets the course, position, and distance traveled on a ship or an airplane.

Network - a series of communications devices arranged to pass information back and forth; all the interdependent parts of the communications system.

Neutral buoyancy - a condition in which the forces of weight and buoyancy offset each other, so that an object will neither sink nor float, but remain at a constant depth.

Nutrients - substances necessary for the growth and survival of living organisms.

Omnivores - animals that eat both plants and other animals.

Paleontology - the systematic study (science) of fossils.

Parabolic - bowl-shaped.

Parasite - an organism that derives food or shelter from another organism, negatively affecting its host. The host loses sustenance, while the parasite loses independence. (Such a creature's mode of existence is called parasitism.)

Pedestal upwelling - a flow of cold, deep water that runs into the coast and is forced upwards to the surface of the water body.

Penal - relating to or involving punishment.

Period - the duration of an orbit; the time required for an object in orbit to return to its starting point.

Photic zone - the part of the ocean where sunlight can reach and photosynthesis is possible.

Photosynthesis - the process by which green plants combine water and carbon dioxide in the presence of sunlight to make sugar and oxygen.

Pinniped - the suborder of meat-eating aquatic mammals that includes the seals and walruses.

Plate tectonics - the theory that the Earth's surface is broken up into irregular pieces, or plates, which move in relation to one another.

Population - a group of individuals of the same species that occupy the same geographic region and interbreed from generation to generation.

Predation - a relationship in which one creature lives by killing and eating another. (One party in this relationship is called the **predator** and the other is its **prey**.)

Pressure - force applied to a given surface area.

Prevailing - in effect most often at the present time.

Priority - something that is chosen, done, or used before all other alternatives.

Producers - green plants and specialized bacteria capable of making food from simple dissolved matter. Green plants use nutrients to produce other food substances.

Profile - a drawing showing a vertical section (side view) of the ground along a surveyed line.

Program - a set of instructions for carrying out a task.

Prop roots - roots that extend from the branches to the ground, forming a support for the growing plant.

Proxy - A person or thing that substitutes for another.

Quadrants - the quarters that result when the Earth is divided by the equator and the prime meridian.

Radiometric dating - the process of using natural radioactivity to determine the age of rocks.

Random - occurring by chance; lacking a definite plan, purpose, or pattern.

Relative location - the comparison of one location to another in terms of a reference point or area.

Renegade - a person who rebels against traditional values.

Robot - a programmable machine with moving parts that can manipulate objects to do some kind of work.

Rope lava - smooth lava of the type geologists describe as "ironed."

ROV - **r**emotely **o**perated **v**ehicle; a type of robot (such as Jason Jr.) that moves in response to commands provided by a human operator or a computer located at some distance.

Satellite - an object that orbits around a larger body.

Scale - the ratio between map distance and real Earth distance; for example, 1 centimeter represents 1 kilometer. Scale varies from map to map.

Scavenger - an animal that feeds on dead or decaying matter.

Scuba (**s**elf-**c**ontained **u**nderwater **b**reathing **a**pparatus) - a diving technology pioneered by Jacques Cousteau and Émile Gagnan.

Scutes - external bony or horny plates, such as those that cover a turtle's shell.

Sea Surface Temperature (SST) - a standard measurement of the average surface temperatures of ocean water.

Seamount - a hot-spot volcano whose top was once above water. The tops of seamounts are worn flat by wave action as they sink back into the crust.

Secede - to withdraw or separate from a state or country.

Sessile - permanently attached, not free-moving.

Shield volcano - a gently sloping volcano of the type most common in the Galápagos. Shield volcanoes are formed almost entirely by fluid lava flow.

Sonar (**so**und **n**avigation **r**anging) - a system that locates submerged objects by means of reflected sound waves.

Species - a population of similar organisms that are capable of interbreeding with each other in nature and do not interbreed with any other populations.

Spectral - having to do with the spectrum, a representation of the wave forms of energy.

Stability - steadiness; the capacity of an object to resist change and remain in a fixed position.

Strata (s. **stratum**) - layers of rock or other material formed at different periods in geological time.

Strato volcano - a steep-sided volcano composed of layers of lava and volcanic ash.

Submersible - a piece of machinery designed to function underwater.

Subsistence - a quality of life that includes only the barest essentials.

Symbiosis - a close interrelationship between two different organisms that may be, but is not necessarily, of benefit to each. (**Parasitism**, **commensalism**, and **mutualism** are different types of symbiotic relationships.)

Taxonomy - the branch of study that deals with the classification of organisms.

Telepresence - the sense of "being there" conveyed by video images of scientific exploration.

Topographic map (also known as a **contour map**) - a map that uses contour lines to show the three-dimensional features of a place.

Tortoise - A type of turtle with specific adaptations for life on land. All tortoises are turtles, but not all turtles are tortoises.

Transmission - the act of sending information in the form of signals or waves.

Transponder - a radio which, upon receiving a designated signal in the form of a coded series of pulses, emits a radio signal of its own that may also be coded.

Twisted pair - an electrical cable consisting of two insulated conductors twisted together with a common wrap.

Undercurrent - a current that flows under other currents, usually in a different direction.

Uplink - a transmission signal sent to a satellite from an Earth station.

Upwelling - a flow of cold, deep water to the surface of a water body. In an ocean upwelling, surface water near the coast is carried out to sea and replaced by cooler subsurface water.

Ventral - belonging to the underside.

Volume - a measure of three-dimensional space (i.e. cubic meters).

Wave - the up and down movement of water that carries energy across its surface.

Weight - a force resulting from the gravitational attraction of the Earth's mass which causes an object to sink.

Windward - the direction from which the wind is blowing.

Zoology - the biological science which studies the animals or the fauna (animal life) of a particular region or district.